

# HOW TO ELIMINATE DISTORTION

---

## SERVICING LOUDSPEAKERS

42RH-1

NATIONAL RADIO INSTITUTE  
ESTABLISHED 1914  
WASHINGTON, D. C.



# STUDY SCHEDULE NO. 42

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

1. Types of Distortion ..... Pages 1-5

Although there are three kinds of distortion, only one type is of great importance to radio servicemen. You are shown that a non-linearity is responsible for amplitude distortion and that improper operating voltages on tubes is a very common cause of this condition.

2. Defects Producing Amplitude Distortion ..... Pages 5-12

Here you study in detail the circuit defects that can cause a tube or iron-core device to produce distortion. Then troubles in push-pull stages are covered. This section serves to show you what to look for when you are localizing the trouble.

3. Defects Producing Frequency Distortion ..... Pages 13-14

This short section gives a listing of the few defects which may cause unusual amounts of frequency distortion. These defects are localized just like those producing amplitude distortion.

4. Localizing Distortion ..... Pages 15-21

Now that you have studied the causes of distortion, you can confidently proceed to localize the trouble to the defective section, stage, circuit and part. This portion of the lesson explains the methods used.

5. Loudspeaker Defects ..... Pages 22-30

As a loudspeaker is a mechanical device, it has many mechanical troubles as well as the usual electrical opens and shorts. These can be recognized by the distortion or noise caused. Here you learn all about them and why they occur.

6. Speaker Repair and Replacement ..... Pages 31-36

After finding the speaker to be at fault, you will have to remove the cone or field and install a replacement. This is a simple procedure in many cases, once the method of installation is seen. You can also send the speaker away for repairs if you desire, and in some instances this is necessary.

7. Answer Lesson Questions and Mail your Answers to N.R.I.

8. Start studying the Next Lesson.

# HOW TO ELIMINATE DISTORTION

## SERVICING LOUDSPEAKERS

### Types of Distortion

WHEN a customer tells you that his receiver doesn't sound right, you have a case of distortion to correct. He may say the set sounds as though the person talking had a "mouthful of mush," or the receiver sounds "tinny or boomy," or he may not be able to describe just what he finds objectionable.

Complete elimination of distortion from an amplifier or reproducer is, of course, an impossibility, for the receiver without any trace of distortion has not yet been made. Your task is to reduce the distortion below the level that causes customer dissatisfaction.

Therefore, when a customer complains about his receiver, be sure you find exactly what he dislikes about its performance. You can't depend on your hearing; even when the receiver is working at its best, you may consider its output distorted, or the customer may complain about distortion which you find unnoticeable. Much depends on what the customer has been used to in the past and the exact quality of his hearing. Remember that the untrained human ear can stand reasonable amounts of distortion indefinitely. Some people even prefer it—for example, those who set the tone control for a greater than normal bass response.

There are three types of distortion: *Frequency, phase and amplitude*. Let us see just exactly what they are, and which you'll be called on to correct most frequently in service work.

#### FREQUENCY DISTORTION

Frequency distortion occurs in a receiver or an amplifier which does not pass all signal frequencies in the audio range equally. Assuming that audible sound ranges from 20 to 20,000 cycles, ideal transmitting and receiving equipment should transmit and reproduce these frequencies with their original relative amplitudes. Fortunately, intelligible and entertaining programs may be had with a smaller frequency range. The usual inexpensive table model radio receiver will have a frequency range of 100 to 3,500 c.p.s.; high-fidelity receivers reproduce from 30 to 15,000 c.p.s. Both receivers will receive programs from a high-fidelity station, but only the one with the wide frequency range can do them full justice.

You cannot tell whether a set has good, bad or indifferent frequency response\* by listening to a program, as the quality of the program itself is unknown. Instead, you must take frequency response curves to determine the frequency range of the equipment.\* Since this is usually a long, tedious procedure, the serviceman generally neglects the frequency range of the receiver except when dealing with high-fidelity receivers, and then only if there is some possibility of a change in response caused by new parts.

\* The procedure used in taking frequency response curves is explained elsewhere in the Course.

## PHASE DISTORTION

Since radio equipment employs coils and condensers, phase shifts occur in the transmission of different frequencies. Thus, several simultaneously transmitted frequencies may not end up in the same phase relationship, but may be advanced or retarded in time. Phase distortion is usually of no importance in sound reproduction, so we will not consider the matter here; you will meet it again in your studies of television.

## AMPLITUDE DISTORTION

When a radio produces signal frequencies that originally did not exist, amplitude distortion is produced—so called because it is the result of departure from the original amplitude wave shape. Since the added signals are usually harmonics of the original, this distortion is sometimes called harmonic distortion.

Now let us see just what causes amplitude distortion. A graphical presentation will show you most clearly.

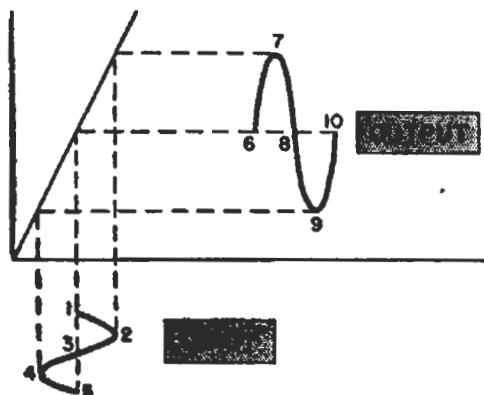


FIG. 1. A straight line characteristic curve will give linear, distortionless output.

No distortion occurs in a device with a straight-line operating characteristic like Fig. 1. Here, the sine wave signal 1-2-3-4-5 produces an enlarged but otherwise exact replica, 6-7-8-9-10. Any device or amplifier with a straight-

line characteristic like this is said to be linear, and will faithfully reproduce the input signal.

As you know, the  $E_g$ - $I_p$  character-

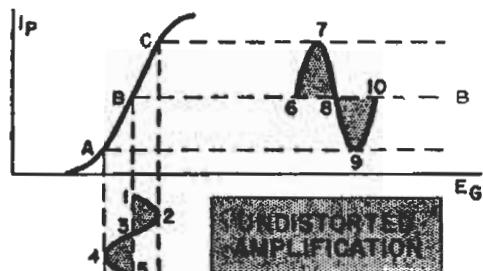


FIG. 2. The actual tube characteristic is never a straight line but is curved, as shown in Fig. 2. Part of the curve is sufficiently straight so that operation on it will not produce appreciable distortion. In Fig. 2 the applied grid signal 1-2-3-4-5 swings the plate current over the almost straight section A-B-C of the

istic of a vacuum tube is never a straight line but is curved, as shown in Fig. 2. Part of the curve is sufficiently straight so that operation on it will not produce appreciable distortion. In Fig. 2 the applied grid signal 1-2-3-4-5 swings the plate current over the almost straight section A-B-C of the

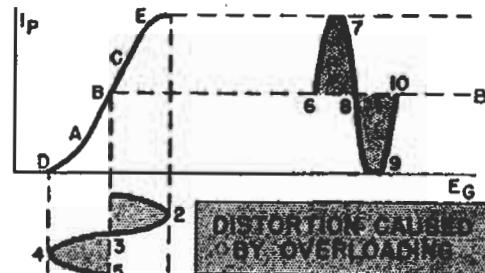


FIG. 3. Too high an input signal swings the operation into the curved regions so distortion occurs.

curve; plate current wave 6-7-8-9-10 has approximately the same shape as the input signal voltage, and no appreciable distortion exists.

**Overloading Effects.** Now suppose we have the same grid bias and plate voltage as for Fig. 2, but apply a larger signal to the grid so that we work into the upper and lower bends of the characteristic (Fig. 3). Here, the signal 1-2-3-4-5 swings the tube operation over range D-B-E, producing the out-

put wave 6-7-8-9-10. The output wave is highly distorted, as the peaks at 7 and 9 are flat. This type of distortion is the result of overloading (too much signal voltage).

The output wave shape in Fig. 3 is still symmetrical, since the upper and lower halves are identical. As you

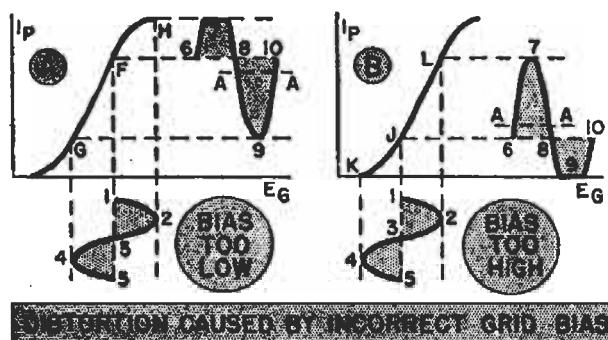


FIG. 4. Even with a normal signal input, too high or too low bias will shift the operating point so distortion occurs.

know, this means that odd harmonics, such as the third, fifth and seventh, have been added to the fundamental. Such distortion is quite noticeable to the human ear.

**Bias Changes.** Suppose that instead of overloading the stage with too much signal, we apply a normal signal and allow the bias voltage to shift. In Fig. 4A, the tube operating curve is the same as in Fig. 2, but the operating point is now point F. The bias voltage has been reduced, allowing a higher average plate current to flow.

Now when we apply grid signal 1-2-3-4-5, we will operate over the curve in the region between G and H. The output wave 6-7-8-9-10 has a flat portion at 7, and the swing from 6 to 7 is much shorter than the swing from 8 to 9, so the upper half of this wave is quite distorted compared to the lower half. Since the two halves of the wave are unsymmetrical, we have an even harmonic distortion.

Similarly, we can get distortion at the lower bend of the curve (Fig. 4B). Here, the bias voltage has been in-

creased so J is the operating point. The input signal swings over the operating region K-L, producing an output wave 6-7-8-9-10. The lower half of the wave is squared off and shorter than the upper half. This is the same distortion as that in Fig. 4A, except that it occurs on the other half of the wave. Since the human ear can't recognize phase shifts of  $180^\circ$ , the two distortions sound alike.

**Plate Voltage Changes.** Distortion like that in Fig. 4 will also occur if the plate voltage changes and the grid bias remains fixed. Fig. 5 shows how.

Suppose the plate voltage is 250 volts and the bias is adjusted to give class A amplification. Then, on curve 1 (the middle operating curve) the operating point will be B and the operating range A-C, so the output curve M is produced—a duplicate of the grid signal.

With the same bias, suppose we increase the plate voltage to 300 volts.

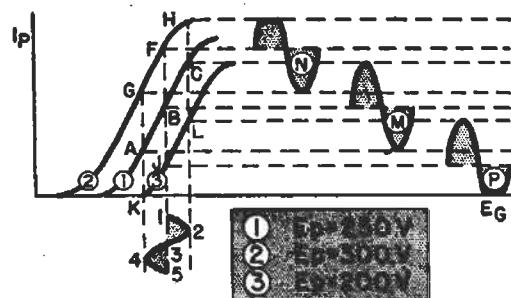


FIG. 5. Incorrect plate voltage can also move the operating point to where distortion becomes excessive.

We will then operate on curve 2, over the upper curve in the G-H region, and get output curve N. Notice that this is the same type of curve as that in Fig. 4A.

If we drop the plate voltage to 200 volts, we use curve 3 and operate in the K-L region of the curve, getting output curve P. This curve is like Fig. 4B.

Thus, overloading the tube, changing the grid bias or changing the plate

voltage may shift the operating point on the tube curve enough to cause distortion.

**Self-Biased Stages.** In a self-biased tube stage, we normally get changes in both the grid voltage and the plate voltage when any defect affects either. Since these two changes tend to compensate for each other, distortion in a self-biased stage is not as great as that shown by our curves so far. However, a self-biased stage cannot compensate fully for changes in operating voltages; some distortion occurs when any change is made, but considerably less than occurs in a fixed-bias stage for the same change.

Remember that changes in screen voltage will have much the same effect as improper plate voltage. The distortion shown in Fig. 5 will occur if screen grid voltage changes make the tube operate over a curved part of its characteristic curve.

Low emission in a tube, caused by a worn-out cathode or by low filament voltage, can also change the operating point of an  $E_g$ - $I_p$  curve so that distortion occurs.

## PLATE CURRENT SHIFTS

In Fig. 2, the average of the plate current is the line  $B-B$ . When the signal is applied, the increase in plate current from 6 to 7 of Fig. 2 is equalled by the decrease from 8 to 9, so there is no change in the *average* value of the plate current. Thus, you should notice no change in the plate current when a signal voltage is applied to a class A stage.

In Fig. 3, the average plate current is the line  $B-B$ . Again the change from 6 to 7 is equal to the change from 8 to 9, so the average plate current will not change. Therefore, the plate current will not tell us when a stage is over-

loading, if the overload causes an output like that in Fig. 3.

However, in Fig. 4A we find something very interesting. The average normal plate current is represented by the line  $F$ . When we apply a signal, the plate current rise from 6 to 7 is not nearly as great as the plate current drop from 8 to 9. Therefore, the new average caused by this signal variation is somewhere near the point represented by the line  $A-A$ . Thus when a signal voltage is applied, the plate current average drops from the  $F$  value to the  $A-A$  value—so a drop in plate current when signals are applied shows you the stage is operating at or near the upper bend in the tube characteristic.

In Fig. 4B, the plate current changes from the average value  $J$  to the value  $A-A'$ —increasing when a signal voltage is applied. Therefore, an *increase* in the plate current when a signal is applied shows the stage is operating on the lower bend of the tube characteristic.

In Fig. 3, we chose an operating point exactly at the middle of the curve. If the actual operating point is higher or lower on the curve, an overloaded input will cause unequal half cycles and, again, a plate current shift. The direction of the shift depends upon whether we are higher or lower on the curve, as in Fig. 4.

*In general, there should be a steady plate current in a class A amplifier, whether or not a signal is applied.* A plate current increase or decrease means some distortion is occurring in that stage. The direction of the change shows whether the stage is operating closer to the upper or the lower bend of the tube characteristic. This test applies *only* to a class A amplifier, like an r.f. stage with no a.v.c. or an audio amplifier—not to a detector or a class B amplifier, where a plate current change always occurs during nor-

mal operation when a signal is applied. As you will learn later, this gives you

a highly useful test for distortion in a class A amplifier.

## Defects Producing Amplitude Distortion

In this section of the lesson we are going to concentrate on amplitude distortion, the type you will most often be called upon to correct. Let us repeat, amplitude distortion exists when the output wave shape no longer resembles the wave shape at the input of the stage or section in which the distortion occurs; the change in wave shape indicates harmonics which were not an original part of the signal.

### DEFECTS CAUSING TUBES TO PRODUCE DISTORTION

Let us see what can happen in each stage of a radio to produce distortion, starting with defects which make tubes distort.

Generally, stages ahead of the first a.f. are free of amplitude distortion, so you can usually concentrate on the a.f. stages, power supply and speaker. Let's see why.

Suppose the r.f. tube  $VT_1$  in Fig.

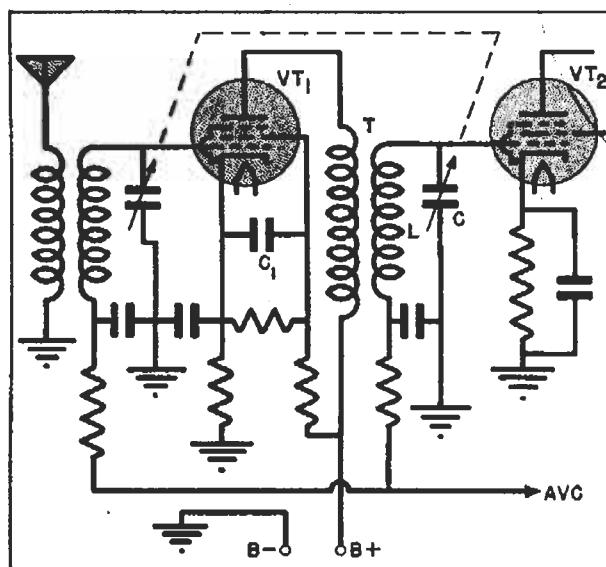


FIG. 6. A typical r.f. stage.

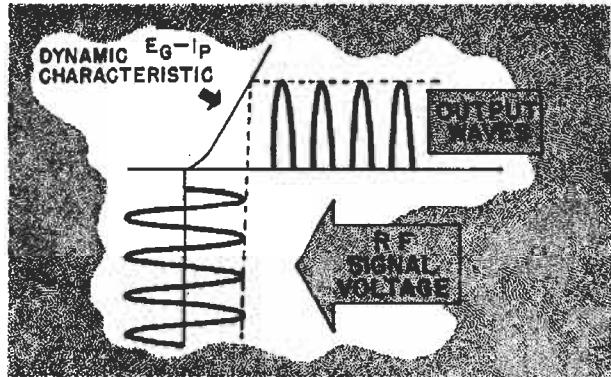


FIG. 7. Operating an r.f. stage at cut-off, the output wave is a series of pulses, but they are reconstructed by the following resonant circuit.

$VT_1$  is forced to operate on the curved portion of its characteristic (Fig. 7) by, say, excess bias and low screen voltage caused by leakage in condenser  $C_1$ .

This practically cuts off the lower half of the plate current wave form. However, when we feed the output signal through the coupling transformer  $T$  to the following resonant circuit, the latter's flywheel action\* restores the lower half of the signal and a replica of the original input signal voltage appears across  $C$  for application to tube  $VT_2$ . Thus the distortion

\* When pulses of energy are fed into a resonant circuit, the condenser charges up on the pulses and then discharges through the coil between pulses. This stores energy in the coil, which in turn charges the condenser with the opposite polarity. When the coil energy is used up, the condenser again discharges. As a result, we have both positive and negative halves of a wave across the condenser if the charging pulses have the same frequency as the resonant frequency of the L-C circuit. This continuing action of the resonant circuit, called the flywheel effect, restores the missing parts of the applied signal.

has been corrected, but the customer will probably complain of low volume or low sensitivity; you'll service the set for that complaint rather than for distortion.

► Similarly, the first detector is designed to operate at the plate current cut-off point just like any other detector. It must cut off half the wave (Fig. 7) to give the necessary mixing action. If a defect occurs *the detector may work on the straight portion of its curve* and become more of an amplifier than a detector. Some mixing of

denser  $C$  breaks down, removing the a.v.c. voltage from the i.f. and preceding tubes.

Then on strong signals, the sensitivity of the r.f. section of the receiver will not be reduced by the a.v.c., so the signal voltage developed across the secondary of i.f. transformer  $T$  will become considerably greater than the d.c. bias across resistor  $R$ . This will allow the tube to operate on both the bends of its characteristic (as in Fig. 3), so both positive and negative signal peaks will be distorted just as if a distorted a.f. signal had been modulated on the carrier at the transmitter. This distorted signal will pass through the second i.f. transformer  $T_1$ , be rectified by the diode detector, and ultimately produce a distorted loudspeaker output. The following resonant circuits cannot correct for this as *both halves of the wave have been affected instead of just one half*.

This overloading can also be caused if  $VT_1$  or some other a.v.c.-controlled tube is gassy and draws grid current. This current will set up a voltage across  $R_1$  with the polarity shown. As a result, the a.v.c. voltage will be opposed by this drop so is effectively decreased, and may allow the r.f. gain to increase enough to produce a signal which will overload  $VT_1$ .

► Trouble may occur in the second detector  $VT_2$ . For example, suppose the r.f. by-pass condenser  $C_2$  opens. This will allow so much r.f. energy to be fed into the first a.f. stage, that it may produce overloading and distortion.

► If resistor  $R_2$  is incorrectly replaced with a resistor of too high an ohmic value, the diode detector may be cut off for short periods because of the grid leak and condenser action of  $R_2-C_2$ . If the charge stored in  $C_2$  can't leak off rapidly enough, weak signal pulses

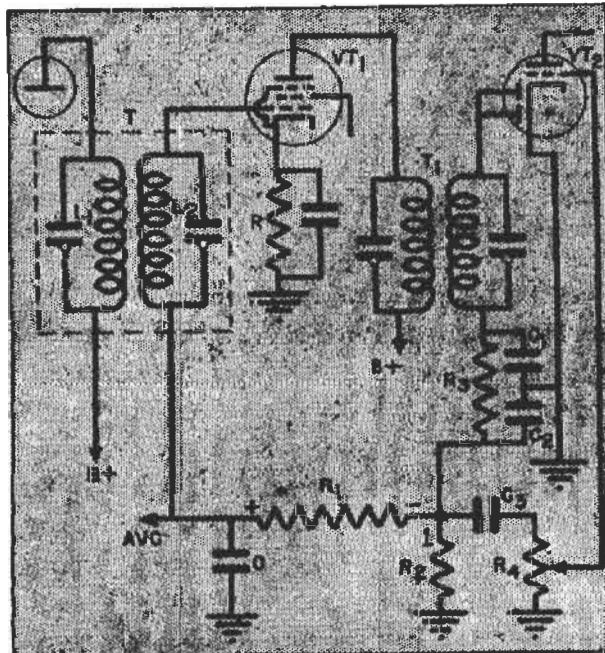


FIG. 8. An i.f. amplifier stage.

the incoming carrier and the locally generated oscillator signal will still occur, but the i.f. output of the detector will be low or circuit noise will arise. Weak reception or noise—rather than distortion—will be the customer's complaint.

Incorrect electrode voltages in the oscillator circuit may make the oscillator block and thus chop up reception. Again, the customer will not recognize this as distortion.

► However, an i.f. stage like that in Fig. 8 may cause distortion when overloaded. Suppose that a.v.c. filter con-

will be cut off, thus producing a distorted output.

**Audio Stages.** Amplitude distortion is most commonly produced in the audio stages. Distortion caused by too much grid bias sometimes occurs in the first a.f. amplifier, which may be the triode section of  $VT_2$  in Fig. 8. During rectification, a d.c. voltage is built up across diode load resistor  $R_2$ , with point 1 negative with respect to ground. If coupling condenser  $C_3$  becomes leaky, the d.c. voltage across  $R_2$  will also appear across the volume control  $R_4$ . Then, as the slider arm on the volume control is moved towards

tive. The self-biasing feature of tube  $VT_2$  in Fig. 9 will compensate for small voltages across  $R_2$ , but usually the coupling condenser leakage progresses to a point where the self bias can't keep up. The tube then operates on the upper half of its  $E_g$ - $I_p$  curve, and a very annoying type of distortion is produced.\*

You can easily tell if distortion is caused by a leaky coupling condenser—simply check with a high-resistance voltmeter, or better still a vacuum tube voltmeter, to see if voltage exists across  $R_2$ . Here's how:

With the aid of a tube chart, locate

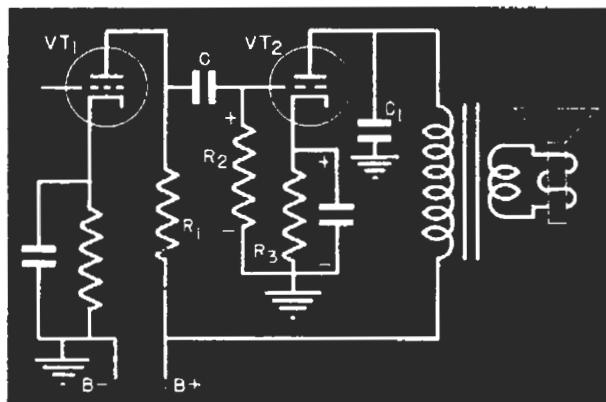


FIG. 9. Most distortion complaints are due to troubles in audio stages like this one.

the point of maximum volume, an increasingly negative bias will be applied to the triode control grid of tube  $VT_2$ , making the triode work on the lower bend of its  $E_g - I_p$  characteristic curve, and so producing distortion. The higher the volume control is turned up, the greater the distortion becomes.

► In a resistance-coupled amplifier, the most common cause of amplitude distortion is incorrect grid bias caused by a leaky coupling condenser. Fig. 9 shows a typical circuit. If condenser  $C$  leaks,  $R_1$ ,  $C$  and  $R_2$  form a voltage divider across the B supply. The voltage developed across  $R_2$  has the polarity shown, making the grid of the tube less negative than normal, or even posi-

the control grid terminal on the socket of tube  $VT_2$ . Place the positive voltmeter probe there, as one end of  $R_2$  is also connected to this point. Touch the negative probe of your voltmeter to the other end of  $R_2$  (or, in this case, to the chassis). Use a high voltmeter range at first, dropping to a lower range if needed. If  $C$  is leaky, you will get an up-scale reading on the voltmeter. If no voltage is present across  $R_2$ ,  $C$  is cleared of suspicion.

\* The next time you are servicing a standard a.c. receiver with a resistance-coupled stage like this, shunt the coupling condenser with a resistance of about 75,000 ohms. This will give the effect of leakage in the coupling condenser and you can become familiar with the distortion produced.

Voltage across  $R_2$ , however, is not definite proof that  $C$  is faulty. Grid current drawn by a gassy tube will also produce a voltage across  $R_2$  with the same polarity as that caused by a leaky coupling condenser. Both defects produce the same type of distortion. To find whether the voltage across  $R_2$  is caused by gas or by a leaky coupling condenser, simply pull the tube out of its socket. If the voltage across  $R_2$  disappears, the tube is gassy; if the voltage remains,  $C$  is leaky. When testing a.c.-d.c. receivers or battery sets—where the test might be upset or damage caused by pulling a tube—unsolder one lead of  $C$  and notice the effect on the voltage across  $R_2$ . If the voltage disappears with  $C$  disconnected,  $C$  is leaky. If the voltage is still present, it is caused by gas in the tube.

**Fixed Bias Troubles.** Fig. 10 shows the audio and power supply circuits of a typical a.c. radio using fixed bias. The bias for the 42 tube is developed across resistors 57 and 61, while the voltage drop across 61 also biases the 75 tube. This circuit is widely used; when distortion occurs in it, there are a number of points to watch.

Leakage in coupling condenser 45 will reduce the bias on the 42 tube and increase its plate current. Since this current flows through resistors 57 and 61, the voltage across them also increases. This in turn increases the bias on the 42 tube, partially compensating for the leakage, so distortion in the 42 tube circuit may not occur until the leakage is so bad the self-biasing action of resistors 57 and 61 can no longer compensate for it. However, only a slight leakage in condenser 45 produces distortion in the 75 tube circuit, because the increase in voltage across resistor 61 is applied directly between the control grid and cathode of this tube. Excess bias on the 75 tube prac-

tically cuts off plate current and causes a choked-up sound, since only the positive peaks of the signal can then be amplified by the tube. The action is the same as that shown in Fig. 4B.

Many servicemen, untrained in effect-to-cause reasoning, stumble on the fact that the distortion does not sound so bad if resistor 61 is shorted. This, of course, removes all bias from the 75 tube except that caused by con-

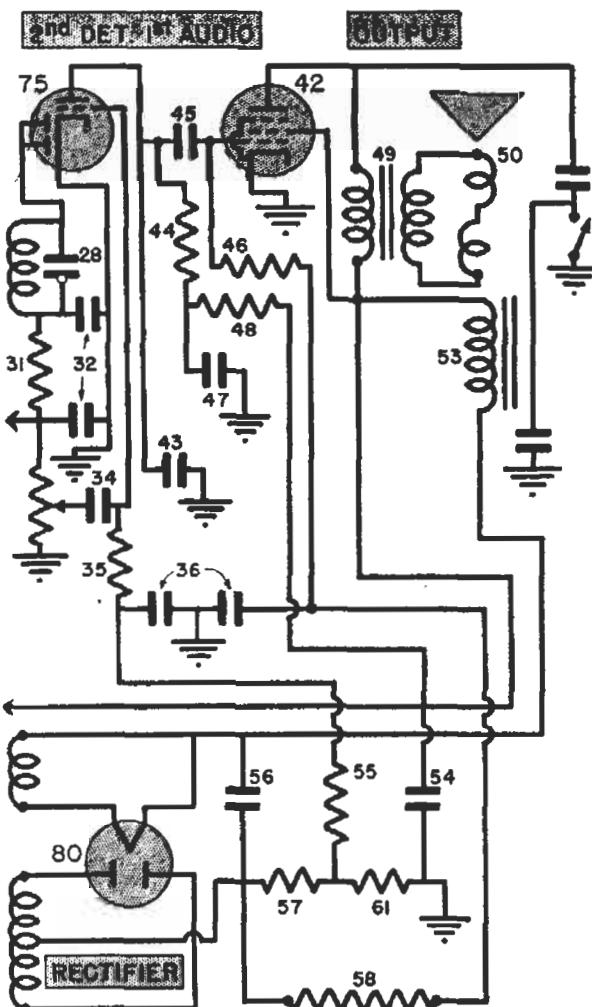


FIG. 10. A good example of trouble in one stage affecting another stage.

vection current through resistors 35 and 55, and so allows reception without too much distortion. However, it does not correct the real trouble, which lies in coupling condenser 45.

If resistor 61 is shorted out, the plate current of the 42 output tube will increase even more, and the tube will

soon wear out. Also, since leakage in condensers is progressive, condenser 45 will become completely shorted before long, so the set will come back for service.

We have gone into detail about this incorrect "repair" for two reasons, first, to impress you with the necessity of finding the real cause of the trouble. *Don't attempt to cure distortion by making changes in design unless you know the effect of the change and the original cause of the distortion.* Second, the fact that shorting out the bias clears up the distortion points to an easy way of finding whether excess bias is causing trouble. In receivers using this popular circuit, simply touch the top cap of the 75 and the chassis with the fingers of one hand. Since your hand is a relatively low resistance, this practically shorts out the bias. If the distortion clears up when you make this check, you can be sure it is caused by excess bias. A voltage check across resistor 46 will show leakage in coupling condenser 45.

This distortion is prevalent in three-way (a.c. - d.c. - battery) portables where the output tube plate current may furnish bias for other tubes. A gassy output tube would increase bias while a weak tube decreases bias.

► As another example, suppose there is no voltage across resistor 46, and the grid-cathode voltage of the 75 tube is normal as measured across resistor 61, yet distortion clears up when you touch the top cap of the 75 tube and the chassis. This, you have learned, shows excess bias—even though the bias appears to be correct. But remember, Fig. 5 showed that the correct bias depends on the plate voltage. Evidently, then, the plate voltage has decreased, so what appears to be a correct bias is actually excessive.

Naturally, you should eliminate the

defect that has reduced the plate voltage rather than adjust the bias. If the plate voltage of only the 75 tube has been reduced, leakage in decoupling condenser 47 is probably the cause. A voltmeter or an ohmmeter will quickly show if this part is faulty.

## DISTORTION IN IRON-CORE DEVICES

Distortion may occur in a transformer-coupled circuit like that in Fig. 11 if the d.c. plate current of tube  $VT_1$  increases because of lowered grid bias, increased plate voltage or any other reason.

The reason is that the d.c. plate current, as well as the a.c. signal current, flows through winding  $L_1$  of the trans-

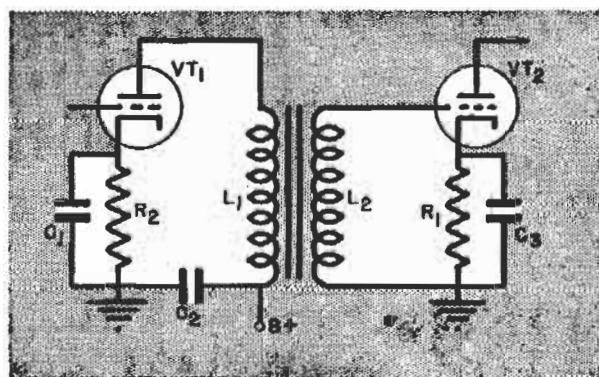


FIG. 11. A transformer-coupled a.f. stage.

former. Audio transformers used in circuits like this are designed to carry a normal amount of d.c. without ill effects. But if the plate current becomes abnormally high, the transformer core may become saturated.

This saturation will make the transformer non-linear in response. A plate current increase will produce practically no increase in flux—and therefore practically no secondary voltage—while a plate current decrease will produce a flux change and a secondary voltage. Thus, if saturation occurs, one-half the signal current in the  $VT_1$  plate circuit will be wiped out by the non-linear transformer action. The secondary output will then be dis-

torted in much the same fashion as is the output of a tube operating with improper bias.

### AMPLITUDE DISTORTION IN PUSH-PULL STAGES

As you know, even harmonics are cancelled in a push-pull stage like that in Fig. 12, but odd harmonics are not. Thus, distortion produced in one-half the wave at each tube (second harmonic distortion) will be removed by the stage. Distortion in both halves of the input wave (third harmonic distortion) will not be removed, but this distortion is not usually appreciable except at high output levels. This relative freedom from distortion is one rea-

be considered satisfactorily balanced.

Such a test is not always conclusive, however. Tubes may check satisfactorily at the reduced voltages of the tube tester, but may not be matched under actual operating voltages. For this reason, several tubes should be tried to find a pair most nearly matched. You will frequently find high-power amplifiers have terminals provided for connecting a meter to check the plate currents individually, and have individual bias supplies so the bias can be adjusted to give equal plate currents.

► Even if the tubes are perfectly matched, distortion may still be passed on to the loudspeaker if different

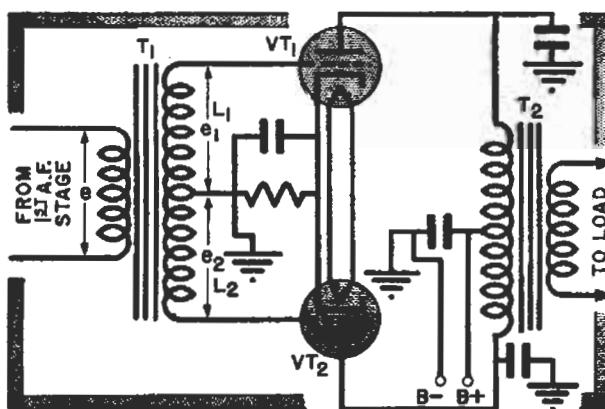


FIG. 12. A transformer-coupled push-pull stage.

son push-pull output stages are so popular.

However, second harmonics will be cancelled by a push-pull stage only if the plate currents of the two tubes are just about equal at all times. This means that the two tubes must have identical characteristics, and be fed the same amounts of signal voltage, for the stage to be free from distortion.

Your first step, therefore, in checking a push-pull stage should be to test the emission of both tubes. When tested on a tube tester having a 0-100 scale, the tubes should give readings within a few points of one another to

amounts of signal voltage are fed into them. In Fig. 12, for example, signal voltages  $e_1$  and  $e_2$  must be equal to prevent distortion. They may not be if transformer  $T_1$  does not deliver equal voltages at all frequencies, if there is a ground in either  $L_1$  or  $L_2$ , or if turns in either winding are shorted.

Replacement is the only cure for a faulty transformer, but you should make sure the transformer is defective before installing a new one. To do so, disconnect both primary leads from the circuit and feed a sine wave signal into the primary of  $T_1$ , preferably a frequency of 400 to 1,000 cycles from an a.f. signal generator, although 6

volts from a power transformer secondary can be used in a pinch. (The low 60-cycle frequency may not produce a balanced signal in less-expensive transformers.) Then compare the output voltages across  $L_1$  and  $L_2$ . You can use an a.c. type v.t.v.m. or a copper-oxide rectifier type a.c. voltmeter to make the comparison. While the latter is not very accurate on high frequencies, such as may be obtained from an a.f. signal generator, it is perfectly all right for comparative readings.

If the voltages are off by more than 10%, trouble is present. You should then disconnect the three secondary leads and check between one of them and the transformer core with a high-range ohmmeter. Normally the leakage should be greater than 20 megohms. A relatively low resistance reading (1 or 2 megohms) shows the presence of leakage between the core and either  $L_1$  or  $L_2$ . No repairs are possible—install a new transformer.

If the leakage test does not disclose a fault, check between each outside lead and the center tap with an ohmmeter. The readings should be within a hundred ohms or so of each other. A much greater difference shows shorted turns on one winding. (The readings will not be the same because, while there are the same number of turns in the outside section as in the section next to the core, the outside turns are larger in diameter. Thus they use more wire and have greater resistance.)

If you are still in doubt, apply a low a.c. voltage to the primary and recompare the voltages across  $L_1$  and  $L_2$  with all leads disconnected from the receiver. If the inequality still exists, the transformer is definitely unsatisfactory. A new one should be installed.

► To check the output transformer, disconnect all leads and apply a low

voltage (1 volt will do) to the secondary. The two primary voltages should be approximately equal. Since a large voltage step-up will occur, use the highest a.c. voltage range of your tester first, then switch to a lower range if necessary.

Shorts or leakage in input and output transformers are not common, however. It is seldom that a properly designed transformer does not provide equal secondary voltages. The usual transformer defect is an open winding.

**Phase Inverters.** Not all receivers use costly and bulky transformers to provide equal input signals to the push-pull tubes. We know that the signals must be of equal intensity and, 180°

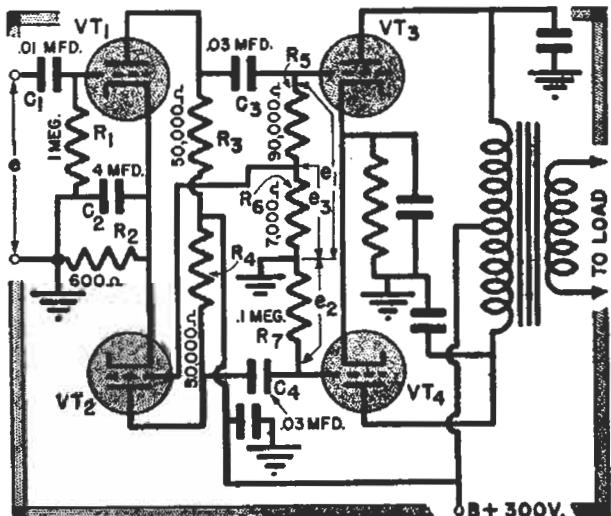


FIG. 13. Using a phase inverter to get the phase reversal necessary for push-pull operation.

out of phase. A tube will shift a signal 180°, so an extra tube and a coupling and supply network may be used to replace an input push-pull transformer.

One typical circuit is shown in Fig. 13. Here the original signal  $e$  is applied to the input of tube  $VT_1$ , amplified by this tube, and applied through coupling condenser  $C_1$  across  $R_5$  and  $R_6$  to the input of tube  $VT_3$  as  $e_1$ . The portion of the signal across  $R_6$  ( $e_3$ ) is fed to the grid of the phase inverter

tube  $VT_2$ . The resulting amplified signal  $e_2$  across  $R_7$ , which is  $180^\circ$  out of phase with signal  $e_1$ , is fed to the other push-pull tube  $VT_4$ . Thus,  $VT_1$  drives both output tubes while  $VT_2$  acts only as a phase inverter. Pulling out  $VT_1$  will block all signals, while pulling out  $VT_2$  will only block half of the push-pull stage.

Since  $VT_1$  and  $VT_2$  are used in similar circuits, they should provide the same gain. Therefore, if the tubes are fed the same amount of signal, the signal voltages  $e_1$  and  $e_2$  applied to  $VT_3$  and  $VT_4$  will be equal as well as being out of phase. By choosing the values of  $R_5$  and  $R_6$  properly, the voltage across  $R_6$  ( $e_3$ ) fed to  $VT_2$  can be made equal to the voltage  $e$  applied to the input of tube  $VT_1$ . Then, with both tubes amplifying these signals the same amount,  $e_1$  will equal  $e_2$ , and distortion produced by even harmonics in output tubes  $VT_3$  and  $VT_4$  will be cancelled by this push-pull action.

Sometimes aging of  $VT_2$  will reduce the phase inverter gain, causing unbalance and distortion. If tubes  $VT_1$  and  $VT_2$  cannot be matched,  $R_5$  and  $R_6$  should be adjusted to produce equal  $e_1$  and  $e_2$  signals. This may be done by measuring voltages  $e_1$  and  $e_2$  with a vacuum tube voltmeter while  $R_6$  is varied in value; when  $e_1$  equals  $e_2$ ,  $R_6$  has the right ohmic value. A convenient way to make this adjustment is to substitute a 10,000-ohm linear-tapered rheostat for  $R_6$ , adjust it until  $e_1$  equals  $e_2$ , then measure the rheostat resistance with an ohmmeter and install a fixed resistor of the same value.

In very bad cases of distortion, remove tube  $VT_2$  and notice the effect

on the tone quality. If there is no change, no signal is passing through  $VT_4$ . You should then check tube  $VT_2$ , tube  $VT_4$ , resistor  $R_4$ , coupling condenser  $C_4$  and the supply voltages to  $VT_4$ .

**Loudspeakers.** As long as the cone motion of a loudspeaker is proportional to the signal currents flowing in the voice coil, no distortion will occur in the speaker. However, the voice coil motion may be non-linear, due to warpage, obstructions in the air gap, etc. We will go into speaker defects, repairs and adjustments in detail later in this lesson. Right now, just remember the speaker can be non-linear too.

**Summary.** You have seen how incorrect voltages will make a tube non-linear in operation, and thus create distortion. This is the case you will generally encounter. Usually, defective parts (except for loudspeakers, which will be taken up later in this lesson) do not cause distortion themselves; rather, the distortion is produced by the changes these defective parts cause in the operating conditions of tubes or iron-core devices.

For example, a condenser may become leaky or a resistor may change in ohmic value, yet signals may pass through them without excessive amplitude distortion being introduced. However, these defects may change the operating voltages of a tube enough to cause serious distortion, or may allow so much current flow through an a.f. transformer primary winding or a.f. choke that the core is saturated, decreasing the reactance so much that distortion occurs.

# Defects Producing Frequency Distortion

Frequency distortion occurs when some frequencies are amplified more than others. Whenever you have a combination of inductance and resistance, capacity and resistance, or inductance and capacity, frequency distortion will always exist, although its amount may be limited by proper initial design. Therefore, there is always some frequency distortion in any audio amplifier, causing losses at both the low- and high-frequency ends of the audio band.

Usually you will correct frequency

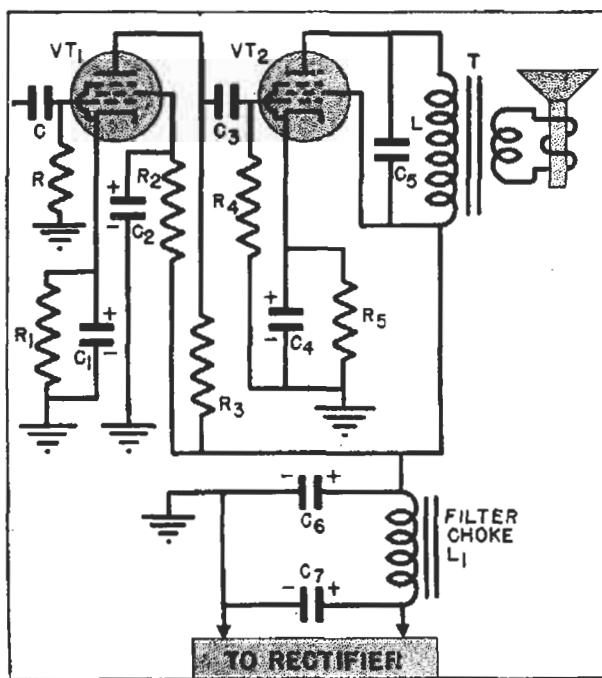


FIG. 14. A typical two-stage audio amplifier.

distortion only when some defect has caused a radical change in the frequency range. Let's see what this defect may be, starting with the r.f. stages.

**Side-Band Cutting.** Some high audio frequency loss will be caused in the r.f. stages by side-band cutting, unless the receiver has a band-pass response. When the tuned circuits resonate sharply, the side bands are

attenuated and the higher audio frequencies in the side bands will not be passed completely (If only one side band is attenuated, amplitude distortion occurs.) This condition may be caused by the design or by too sharp peak alignment. The alignment can be quickly corrected with a frequency-modulated signal generator and an oscilloscope, by staggering adjustments slightly so as to broaden the peak.

Severe side-band cutting can also be caused by regeneration, although the trouble causing regeneration usually causes oscillation before a serviceman is called in. Treat regeneration just as you would oscillation complaints.

## FREQUENCY DISTORTION IN A TYPICAL AUDIO CIRCUIT

Fig. 14 shows a typical two-stage audio amplifier. Let's see how various troubles may cause frequency distortion.

If either coupling condenser  $C$  or  $C_3$  opens, the reduction in capacity will cause severe frequency distortion. The volume will be cut down tremendously, but enough residual capacity will be present in the wiring and between the broken ends of the condenser leads to allow very high-frequency audio notes to pass. This defect can easily be distinguished by the great reduction in volume.

► Condenser  $C_5$  is used in the output circuit to prevent possible oscillation. If this condenser opens, there will be no effect on low audio frequencies, but more high audio frequencies (normally by-passed by  $C_5$ ) will be passed by the stage to the speaker.

► An open in condenser  $C_1$  or condenser  $C_4$  removes the by-passing across the bias resistors, allowing de-

generation to occur. This will reduce amplification somewhat, but will also flatten the frequency response and give better fidelity. However, if small amounts of capacity remain in these condensers, the higher frequencies will be by-passed. There will then be less degeneration and a rising response at these frequencies.

► Signals flowing in the plate circuit of  $VT_2$  normally pass from the plate through  $L$ ,  $C_6$  and  $C_4$ , back to the cathode. The primary  $L$  acts as the plate load across which the amplified audio voltage appears.

If  $C_6$  loses capacity, the external plate-to-cathode path for *low audio frequencies* will be  $L$ ,  $L_1$ ,  $C_7$  and  $C_4$ . The plate load will be  $L + L_1$ ; the amplified signal voltage will divide between  $L$  and  $L_1$ , most of it appearing across filter choke  $L_1$  because its inductance is much higher than that of  $L$ . The *higher audio frequencies* still go through the remaining capacity in  $C_6$  or find a fairly low reactance path through the distributed capacity of  $L_1$ . As a result, most low-frequency voltages are developed across  $L_1$ , most high-frequency voltages across  $L$ . Since audio signals developed across  $L_1$  cannot be transmitted to the loudspeaker,

there is a marked loss of low and medium frequency notes.

This action will not occur in a push-pull output circuit. But, if the schematic shows a single-ended\* output stage and you encounter a loud, high-pitched response with a marked absence of bass notes, accompanied by a loud hum, check the output filter condenser. This is easily done by shunting another condenser of about the same capacity (working voltage at least as high as the original) across the condenser you suspect is open. If you are right the tone will at once clear up. When making this test you must observe the polarity markings on the test condenser. In this circuit, touch the negative lead of the condenser to the chassis and the positive lead to the + terminal of  $C_6$ . If the latter is not readily accessible, use the screen of the output tube (since it is directly connected to the positive terminal of  $C_8$ ).

Frequency distortion in high-fidelity receivers may be caused by a slight change in a part value or by misalignment. In ordinary receivers, defective parts are usually responsible, as we shall see later in this book.

---

\* Only one tube—not push-pull.

# Localizing Distortion

The causes of distortion may be found by using the same general procedures used for other defects: confirming the complaint, looking for surface defects, effect-to-cause reasoning, then localization to a section, stage, circuit and part.

When confirming the complaint, listen carefully to the receiver. Different defects produce somewhat different distortion sounds, and a little ear training will often help you go right to the trouble.

In the less obvious cases, particularly when dealing with a high-fidelity receiver, be sure to get all the clues the customer can give you. For example, find out whether the distortion is noticeable as soon as the set is turned on. A distortion which occurs only after the set has warmed up a half hour or so is usually caused by gassy tubes or by heat warping the speaker frame. Many other worth-while clues like this can be picked up by careful questioning.

**Interference Problems.** Before going into the receiver, be sure the "distortion" is not produced by external causes. The customer will frequently confuse distortion with interference.

Perhaps one of the most annoying types of interference is chopped-up reception caused by picking up two or more stations at the same point on the dial. If the customer's radio is band-passed to 10 kc. or more, picking up two stations 10 kc. apart and modulated with a 5-kc. sound causes garbled reproduction which sounds so much like "monkey chatter" it is referred to by this term. Nothing can be done with an ordinary receiver except to reduce fidelity by peaking the tuning system. In a high-fidelity receiver with variable band width, compressing the band

width will help.

Sometimes when interfering stations are distant, a change in antenna direction will favor one station more than the other and allow satisfactory reception of the favored station. This may even help when the stations are on the same frequency, but in general it is best for the customer simply to tune elsewhere on his dial. Interference of this type is more prevalent at night and during the winter months, because then better long-distance reception is possible. In the summer time reception may be entirely satisfactory, for then not as many distant interfering stations will be picked up.

Now, let us see what can be done about a real case of distortion.

**Surface Defects.** An inspection for surface defects is not very revealing, since few troubles causing distortion are visible to the eye.

Of course you should first test all tubes and replace any bad ones. The speaker cone should be examined to see if it is torn or crushed. You should also look for a blue glow between the electrodes\* of glass tubes, which indicates either the presence of gas or excessive plate current caused either by a tube defect or by incorrect operating voltages.

Look for corroded connections at the power supply terminals of battery receivers; these might lower operating voltages and so cause distortion by shifting the operating points of tubes.

Sometimes the wrong tube will be placed in a stage. Always check on this when a diagram or tube layout is available.

---

\* Pay no attention to a glow on the glass envelope as this is natural; also a glow should appear between the electrodes of a gaseous type rectifier such as a type 82 or OZ4.

A worn volume control which makes a poor contact between the slider and the resistance element can chop up the signal (the customer will call this a distortion sometimes) or cause intermittent reception, noise or hum. If you notice any noise as the control is adjusted, replace the control.

► After making the usual check for circuit defects, you can then resort to effect-to-cause reasoning. However, there are many causes of distortion; not until you distinguish them by their sounds is effect-to-cause reasoning greatly helpful. Since the most common sources of distortion in the average receiver are leaky coupling condensers or gassy tubes, you might check these points, but it is usually best to resort to section and stage isolation procedures.

### DEFECTIVE SECTION ISOLATION

There are two ways of making a section isolation. For convenience, we divide a receiver into: 1. The a.f. section, which includes everything between the output of the second detector and loudspeaker; and 2, the r.f. section, which includes everything between the antenna and the first a.f. stage. You can isolate the defective section either by clearing one of them of any fault or by finding the one which is at fault.

First, you can tune in a signal from a broadcast station and listen at the output of the second detector, either with a signal-tracing device having an audible output or with a pair of phones—or you might even feed from the second detector into an audio amplifier-speaker combination which is known to be in good condition. If there is no distortion at the output of the second detector, the trouble must be in the a.f. amplifier.

To check the audio amplifier, feed

an audio signal through it from another receiver or from a phonograph record. If the receiver is a phono-radio combination, be sure to use a phonograph record. If the output from the record is undistorted, the trouble must be in the r.f. amplifier. If the output from the record is distorted, as well as that from the radio program, the trouble is in the audio amplifier.

Many servicemen keep a phonograph record player in their shops for checking receivers for distortion. Naturally, a good quality pick-up must be used, as well as a symphonic recording with a wide tonal range and plenty of high- and low-frequency notes, in order to judge the fidelity of the receiver.

You can also check the audio amplifier by using an a.f. signal generator and a c.r.o. A comparison of the input and output wave forms on the c.r.o. screen will show if distortion exists. Details of this test will be given later. Incidentally, an audio generator alone can't be used to localize distortion, because your ear won't notice distortion in a single tone.

### LOCALIZING THE DEFECTIVE A.F. STAGE

Let us assume you've traced the trouble to the a.f. section of the receiver. Now, let's see how you can localize the trouble to a particular defective stage. There are two methods: you can take voltage and current measurements, or you can use some form of signal tracing.

**Voltage and Current Readings.** As you recall, amplitude distortion is usually caused by abnormal tube operating voltages. By taking voltage measurements and comparing them with those given by the manufacturer, you can determine when the grid bias, plate voltage or screen voltage is not normal. If you do not have the manu-

facturer's information, you can tell from experience if the measurements are unusual.

► Current measurements quickly spot class A stages in which distortion exists. Just connect a current meter in the plate circuit, as in Fig. 15, and notice whether the reading changes when signals are applied. You learned from Figs. 4 and 5 that distortion causes a change in the average plate current when signals are applied.

The direction in which the current

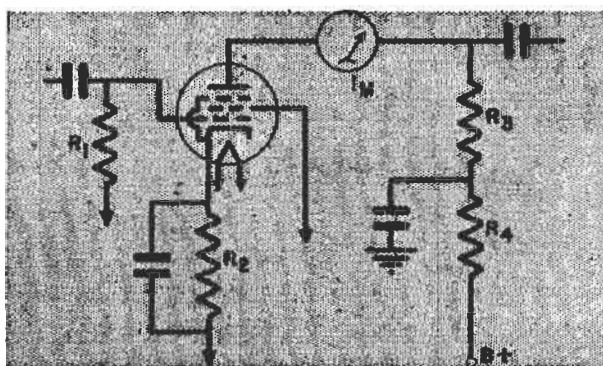


FIG. 15. Distortion is occurring if the plate current changes when signals are applied to a class A stage.

changes is important. The table in Fig. 16 shows probable causes of either an increase or decrease in the average plate current when a signal is applied to the input.

It's easier to make this check if you measure the plate current indirectly, instead of breaking the plate or cathode circuits for a direct measurement. Notice the plate current of the tube in Fig. 15 flows through resistors  $R_2$ ,  $R_3$  and  $R_4$ . If the plate current changes, the voltage across these resistors will also change, so all you need do is connect a voltmeter across one resistor and notice whether the reading changes when a signal is applied. An increase in voltage means an increase in plate current, while a decrease in voltage means the plate current has decreased.

This method is practical where you have just one or two stages to work

with, as in most modern receiver audio amplifiers. If you are dealing with an amplifier having a number of stages, some means of further isolation will probably find the trouble faster. Let us now consider some of the signal-tracing methods.

**Signal Tracing.** Fig. 17 shows a typical audio amplifier. Underneath the diagram are the various pieces of equipment which can be used to localize the stage producing distortion: *A*, a signal tracer with an audible output indicator; *B*, a pair of phones with a protective condenser in series; *C*, a phonograph pick-up; *D*, an a.f. signal generator; and *E*, a cathode ray oscilloscope.

When using the signal tracer or the phones, you can use either the output of a second detector or a phonograph record as the audio signal source, feeding it into terminals 1 and 2 of the amplifier. First, tune in a station (or play a record) and notice the distortion level of the loudspeaker output. Next, it's a good idea to mute the set loudspeaker so you won't hear it while

MILLIAMMETER DEFLECTION	GRID BIAS	PLATE VOLTAGE	SCREEN VOLTAGE
UP	TOO HIGH	TOO LOW	TOO LOW
DOWN	TOO LOW	TOO HIGH	TOO HIGH

FIG. 16. This chart shows what may be wrong to produce a plate current change up or down.

you're trying to listen to the audio output of your signal tracer. To do so, disconnect the voice coil of the speaker and connect a 10-ohm, 5-watt resistor in its place across the secondary of the output transformer.

Then, using either the signal tracer or the phones, start at the input of the amplifier and move to the output, looking for the point where the distor-

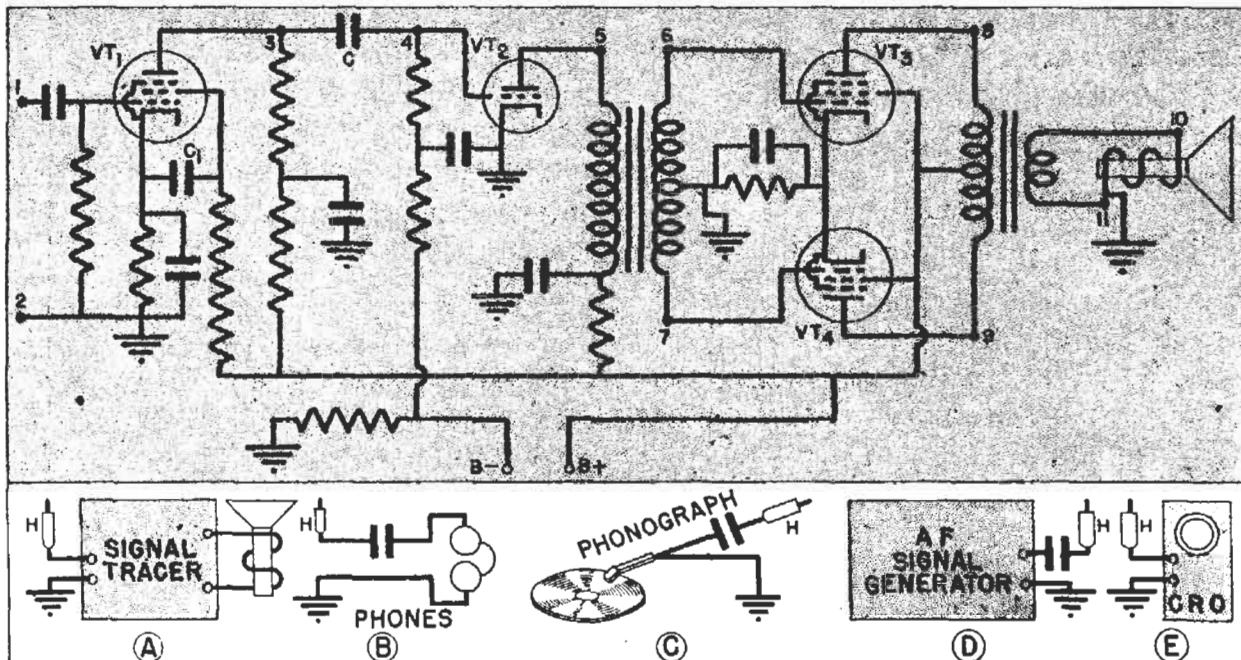


FIG. 17. Here are the devices that can be used to localize the distortion in an audio amplifier like the one shown above.

tion originates. The signal must be kept at a low level when using phones, to avoid overloading them.

Start by sampling the signal fed into the a.f. system. To do so, clip one terminal of the test instrument to the receiver chassis, and connect the hot probe (marked H) to point 1. The signal should be clear and free from distortion at this point—if not, the r.f. section rather than the a.f. section is at fault. Next, move the hot probe to terminal 3 to see if tube VT<sub>1</sub> introduces distortion. If it does, you have isolated the trouble to this stage; check the tube, the operating voltages and the parts to find the exact cause.

No trouble can occur between points 3 and 4 that will result in amplitude distortion appearing at point 4. If coupling condenser C is leaky the signal at 4 will remain undistorted, although the change in the grid voltage of VT<sub>2</sub> will distort its output. An open coupling condenser will cause weak reception and frequency distortion, not amplitude distortion.

Thus, the next place to sample the signal after point 3 is at 5. If it is all

right here, check the signal applied to output tubes VT<sub>3</sub> and VT<sub>4</sub> by connecting the hot probe first to point 6 and then to point 7. (A signal tracer, which indicates the signal level, will show if the output tubes are receiving equal signals better than a headphone.) The signal should then be checked at point 10. (If one terminal of the voice coil is not grounded as shown, unclip the test lead from the chassis and connect it to point 11 while the hot probe is on point 10.) If the signal is clear at point 10 but the loudspeaker reproduces distortion when reconnected, the speaker itself is at fault.

**Using a C.R.O.** If a c.r.o. is used to sample the signal, the signal source should produce a single frequency, preferably having a sine wave form. This means an a.f. signal generator must be used. Then the signal samples gathered at strategic points in the amplifier can be directly compared to the source signal; in this way the nature of the distortion and the stage in which it originates can be accurately determined.

Fig. 18 shows in block form how the a.f. signal generator and c.r.o. are con-

ected to the amplifier under test. The hot lead of the signal generator is connected to the amplifier input (point 1 in Fig. 17). The *hot* vertical amplifier lead of the c.r.o. is connected to the point under test through a single-pole, double-throw switch *SW*. When this switch is thrown to point *a*, the c.r.o. "sees" the signal fed into the amplifier. By throwing the switch to point *b*, the signal being sampled can be seen and mentally compared to the original signal. Of course, the *amplitude* of the sample signal will usually be greater than that of the original, but if the *wave shapes* of the two signals are the same, no distortion exists.

in Fig. 17, touch the hot c.r.o. test lead to points 1, 3, 5, 6, 7, 8, 9 and 10. When the pattern first changes shape, you have just passed through the defective stage; you can then find the actual defect with your voltmeter and ohmmeter.

As the c.r.o. probe is moved from 1 to 9, the signal strength increases, so you should reduce the c.r.o. vertical gain to keep the pattern from becoming larger than the original. When moving from point 9 to point 10, however, there is a sharp reduction in signal voltage; here the vertical gain must be increased to bring the pattern up to normal size. Since the c.r.o. shows

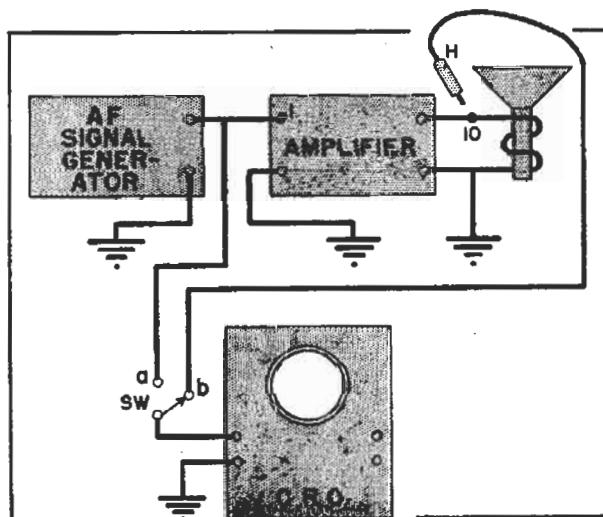


FIG. 18. The connections for a c.r.o. when tracing for distortion.

Switch *SW* can be eliminated if you connect the hot c.r.o. lead to the hot signal generator lead, then, with a piece of onion skin paper, trace over the sine wave signal produced by the signal generator on the c.r.o. screen. You can then compare this trace with the signal at other points.

When you have the a.f. signal generator and c.r.o. connected as described above, set the c.r.o. timing and synchronizing adjustments to produce 2 or 3 cycles of the input signal on its screen. You are then ready to compare signals. To do this in a circuit like that

signal strength as well as wave form, you can use it to determine whether the signals fed the push-pull output tubes at points 6 and 7 are equal in magnitude.

► A number of typical c.r.o. patterns and their probable causes are shown in Fig. 19. These patterns are for a c.r.o. with negative input polarity;\* if the input polarity of your c.r.o. is positive, the pattern will be inverted. The actual causes, of course, are found when

\* The method of determining c.r.o. input polarity is described in another lesson.

the stage itself is analyzed. If you obtain a c.r.o., you will quickly learn to interpret distortion patterns in terms of the defect producing them.

**Signal Injection.** Instead of sampling the signal at various points in the amplifier, you can feed a signal into some point to see if the distortion occurs between this point and the loudspeaker. (Of course, you should not mute the speaker if you use this meth-

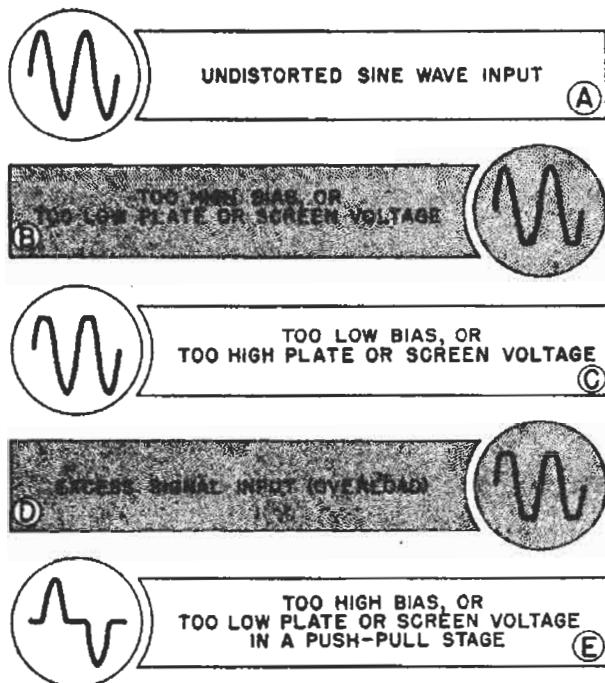


FIG. 19. These are the c.r.o. patterns which disclose conditions in an amplifier.

od.) The easiest signal source to use for this is a phonograph pick-up. However, a pick-up does not have sufficient output to work from points near the loudspeaker; for these points you should use a two-stage, hum-free test amplifier having minimum distortion (like the one in Fig. 20) with the pick-up. Adjust the test amplifier output by its volume control so that the sounds from the receiver loudspeaker approach normal room volume.

This amplifier is satisfactory for checking anywhere in the amplifier, except directly across the voice coil. Therefore, you will have to start testing at point 8 or point 9 of Fig. 17.

The output will tell you whether the output transformer and loudspeaker are in good condition.

Do not inject the signal at points 6 and 7, for this feeds only one output tube at a time and so itself produces distortion. Instead, feed the signal into point 5, then into point 4, and finally into point 1. As more stages are included, reduce the phono volume to prevent overloading the receiver amplifier. When you reach a point where distortion is produced, the defective stage has just been included in the stages between the phono output and the receiver loudspeaker.

Remember, any one of these isolation tests will locate the defective stage. Which one you use in your ser-

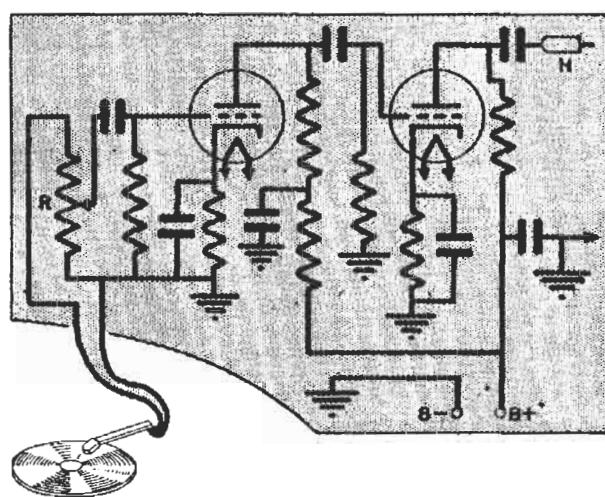


FIG. 20. A record player and amplifier combination like this can be used to feed a test signal into the amplifier being serviced.

vice work depends on your own inclination and the equipment available.

#### ISOLATING THE DEFECTIVE R.F. STAGE

If your preliminary tests show the trouble is in the r.f. section, your first step should be to use effect-to-cause reasoning—remember that distortion in r.f. stages may be caused by overloading or by a defect in the second detector circuit.

If effect-to-cause reasoning fails,

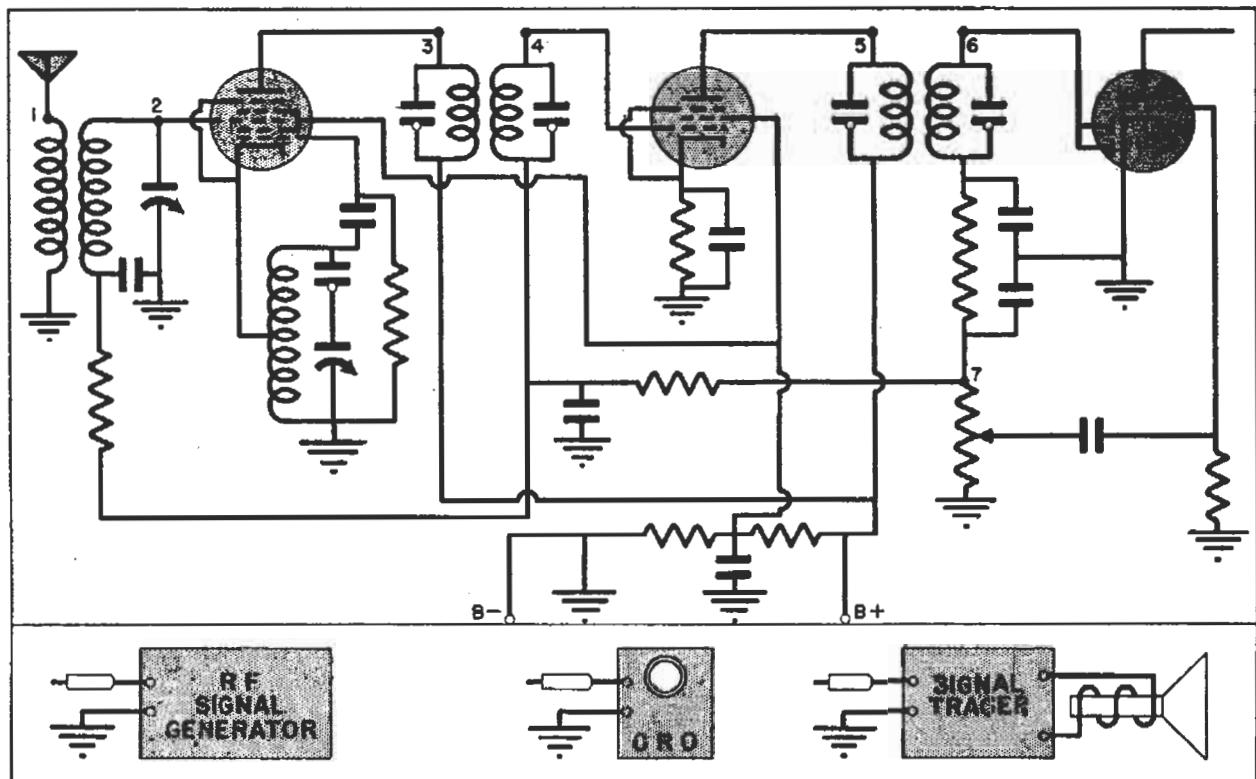


FIG. 21. Here are the devices that can be used to localize distortion in an r.f. amplifier like the one shown above.

you can isolate the defective stage with an r.f. signal tracer. To check an r.f. system like that in Fig. 21, tune in a station that causes the loudspeaker output to sound distorted. When you know what the distortion sounds like, substitute a resistor for the speaker as you did in checking the a.f. system. Connect the ground lead of the signal tracer to the chassis, then hold the signal tracer hot probe on point 1 and tune the tracer to the signal. Move the probe to point 2. If you find distortion at either of these points, the station output itself is distorted.

Next, pass to point 3 and tune the signal tracer to the i.f. of the receiver, then move the hot probe to points 4, 5 and 6 in turn. When you first hear distortion, the defective stage has just

been passed. If you find none, check at point 7 with the audio section of the tracer to learn whether detection has introduced distortion.

The c.r.o. is not very satisfactory for sampling the signal in r.f. circuits, since its sweep frequency is not high enough to give a useful picture of the carrier wave shape. However, the c.r.o. may be used with an r.f. signal tracer by connecting its vertical plates to the a.f. output of the tracer. When this is done the receiver should be fed from a sine wave modulated signal generator. Sample the signal with the tracer in the manner just described, and watch the sine wave modulation on the c.r.o. screen. When the wave shape becomes distorted, you have just passed the defective stage.

## COMMON CAUSES OF AMPLITUDE DISTORTION

R.F.	DET.	A.F.	SPEAKER
Gassy a.v.c.-controlled tube (including Magic Eye)	Incorrect voltages — Diode load resistor too large	Leaky coupling condenser — Gassy tube — Leaky or shorted by-pass condenser — Volume control worn — Tubes in push-pull stage unbalanced — Incorrect supply voltages	Voice coil rubs pole piece — Spider cracked — Cone brittle or torn — Cone unglued — Speaker field open (when not part of voltage supply circuit) — Armature of magnetic speaker not centered
Leaky a.v.c. filter condenser			

## Loudspeaker Defects

Most loudspeaker difficulties are mechanical. Therefore, once effect-to-cause reasoning has localized the trouble to the loudspeaker, a visual inspection will generally lead you right to the cause of the trouble.

The speaker is likely to be involved only when the complaint is distortion, noise, weak reception, a dead set or hum. Speaker troubles rarely cause intermittent reception or oscillation, although hardened mounting supports may help cause microphonic howl. The hum level produced by the speaker itself (not that coming from the set) is above the design value only if the connections to a hum-bucking coil are reversed; this is cured by a simple reversal of the connections.

Distortion is one of the most common complaints caused by a defective speaker. Speaker distortion is of a peculiar nature, accompanied by rasp-

ing, scraping sounds; it can be localized, but experience will quickly teach you to identify it as soon as it is heard.

Let us now briefly review loudspeaker types, then take up speaker troubles. In the next section of the lesson, we will cover the practical problems of repair and replacement.

### SPEAKER TYPES

The most common loudspeaker today is the moving-coil type, in which a voice coil is mounted so it can move in a fixed magnetic field. The audio voltage fed to the voice coil produces a varying magnetic field around it. The interaction between the two fields makes the voice coil move back and forth. A cone or diaphragm fastened to the voice coil moves with it, creating sound waves in the surrounding air.

There are two general types of moving-coil loudspeakers. In one, the fixed field is produced by a field coil. This type is known as the electrodynamic or dynamic loudspeaker. The second type uses a powerful permanent magnet to establish the fixed field; it is called the permanent-magnet dynamic or the p.m. dynamic loudspeaker.

The only other kind of speaker used much today is the magnetic type, which we will describe later.

**Moving-Coil Systems.** Let us first see just how moving-coil speakers are constructed.

The paper or fabric cone is supported by a paper, cloth, or leather ring or rim, which is mounted on the speaker

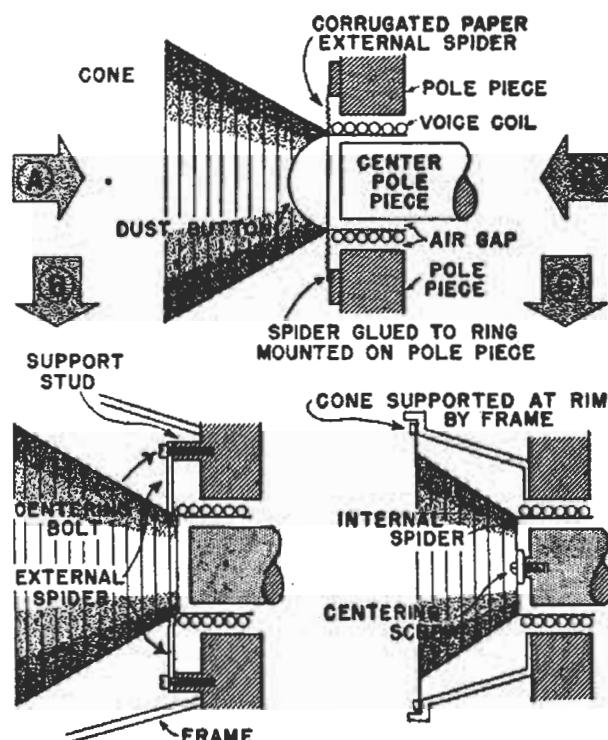


FIG. 22. The three types of loudspeaker spiders.

frame. The voice coil, which consists of several turns of wire on a thin fiber or bakelite tube, is fastened to the apex of the cone. To keep the voice coil properly positioned in a relatively small air gap between the center pole piece and the front pole piece of the loudspeaker, the apex of the cone is supported by a "spider"—a highly

flexible paper or fiber support, so constructed that it will normally hold the voice coil part in and part out of the air gap when no signals are applied. When signals are applied, the spider must not greatly impede the movement of the voice coil and cone but must act as a spring or restoring force, tending to move the coil back to its at-rest position.

► There are two types of spiders, one within the circumference of the voice coil form and the other outside the cir-

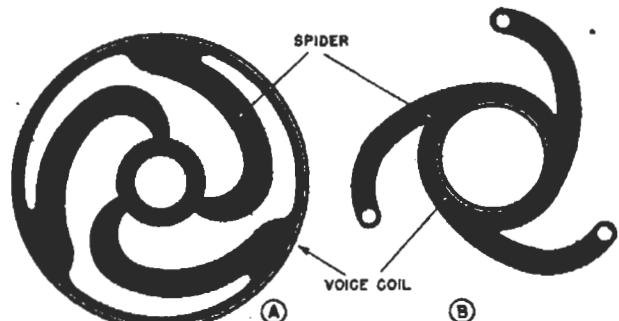


FIG. 23. A face view of an internal spider (A) and an external spider (B).

cumference, known respectively as the internal and external spiders. Fig. 22A shows an external spider made of a circular paper ring glued to supports mounted on the pole piece. In 22B is an external fiber spider, while in C an internal fiber spider is shown. The general shapes of these (fiber) spiders can be seen in Fig. 23. Notice that the fiber spiders have a curled construction so they will move in and out. The paper spiders have ridges or corrugations in the paper so that the spider can stretch readily under the influence of cone and voice coil movements.

► The cone-voice-coil assembly must be entirely free to move under the influence of the desired signal. The voice coil must not strike the pole pieces nor encounter any foreign objects in the air gap which might impede the back and forth motion. The cone must not vibrate at any frequency other than that contained in the original signal,

nor should it produce any unwanted noises. Let us now see just what can cause trouble in the moving system.

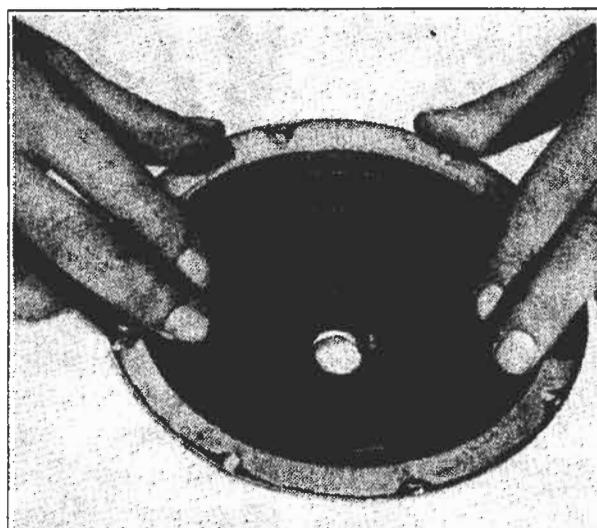
### VOICE COIL RUBBING

If the voice coil touches the pole pieces, free in-and-out motion of the cone is interfered with and signals will be distorted. High-frequency audio signals cause only a slight movement of the voice coil, but at low frequencies a large movement of the voice coil will take place. Since the greatest rubbing occurs during the greatest voice coil movement, signals composed of low

pressure, still keeping your finger tips in contact with the cone rim. If the voice coil hits the pole pieces you can generally hear a scraping sound, and you can often feel the scraping through the tips of your fingers.

► Let's see what can cause this trouble and what may be done to correct it.

If the speaker frame is bent, this will tilt the cone, and in turn tilt the voice coil so that the voice coil will rub against the pole pieces. To correct the trouble, bend the frame in the proper direction and, if necessary, recenter the voice coil.



Testing the centering of the voice coil by pressing on the cone rim and listening for rubbing sounds.

notes are more affected by the voice coil hitting the pole pieces than are signals composed of high notes. For example, male voices will be affected while female voices will be clear, so you can make a preliminary check for this trouble by tuning in a male voice and setting the tone control for maximum bass response.

If such a test indicates rubbing, remove the speaker from the cabinet. With the speaker on its back (cone up), press in on the cone rim lightly with your finger tips, then release the

The frame may be warped by heat from the speaker field. In most cases like this, there will be no distortion for a half hour or so, then distortion will begin and gradually become worse. Bending the frame back into shape or replacing the speaker is the cure. This trouble occurs most commonly with small, light-weight speakers such as those found in a.c.-d.c. receivers.

The voice coil is wound on a light-weight fiber or bakelite tube. This tube is perfectly circular when new, but heat or moisture may warp it out

of shape and allow it to rub against the pole pieces. The remedy is to install a new cone.

The cone itself may lose shape; this will bend the spider and throw the voice coil off center. If the cone is bent or crushed on one side, try to straighten it. Should this prove impossible or should the voice coil still rub, recenter the voice coil. In extreme cases, a new cone will be required.

Loose turns on the voice coil will allow rubbing, since the clearance between the voice coil and pole pieces is slight, especially in small speakers. If possible, remove the cone (instructions will be given later) and voice coil. When this has been done, see if the loose voice coil turns can be recemented to the voice coil form. Before cementing, put a cork in the voice coil form to prevent warping. Allow at least a half hour for the cement to set, then remove the cork and install the cone in accordance with the instructions given later for new cone installation. Removal of a cone for repair is a difficult procedure which is not always successful. If the cone is damaged during its removal, chalk it up to experience and install a new one.

► Cones and voice coils are not the only speaker parts which cause this trouble. The spider is often at fault, which means a new cone is necessary. The spider may fatigue and lose its ability to return the voice coil to its normal position. Then the voice coil will be too deep in the air gap, so at times the end of the voice coil may strike the bottom of the gap. A new cone should be installed, although sometimes a thin metal washer placed under the spider and the centering screw or bolts will lift the voice coil out of the air gap sufficiently to give fair results.

► Corrugated spiders which are fa-

tigued or which sag because of moisture absorption cannot be shimmed up. Sometimes an inexperienced serviceman makes temporary repairs by shoving a small wad of cotton batting between the cone and the speaker frame. This trick is also used at times when a warped or crushed cone lets the voice coil strike the pole pieces. The results after a short time are nil—the only satisfactory repair is to install a new cone.

## PARTICLES IN THE AIR GAP

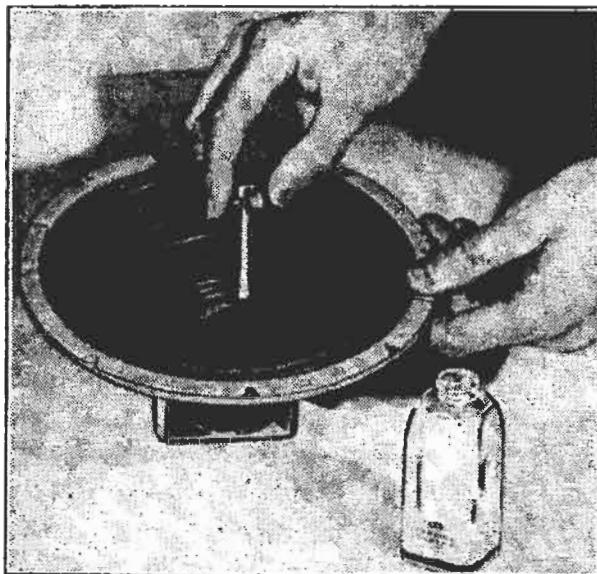
Particles of dirt or iron filings in the air gap will also interfere with free voice coil movement. When you check for an off-center voice coil, you can feel the coil turns bump as they pass over these obstructions. Sometimes you can get out dirt particles if you feed 2.5 volts or less of 60-cycle a.c. to the voice coil (a filament winding on the power transformer can be used as the voltage source) and put the speaker face down on the workbench. The field must be energized so the voice coil will move back and forth. Non-ferrous particles will often work themselves out of the air gap. Lightly striking the back of the pot (field enclosure) with a wooden mallet or large screwdriver handle will help. (Don't try this on a p.m. speaker, as you may demagnetize the permanent magnet by striking the back of the center pole piece.) Compressed air blown into the air gap from a bellows or hand pump is also an effective means of removing dirt.

When ferrous (iron) particles are lodged in the air gap, the magnetism holds them fast and makes their removal difficult. If the speaker is a dynamic, disconnect the field and apply 110 volts a.c. from a wall outlet across the field with the set turned off. Place the speaker face down and rap it sharply on the back of the pot several

times. At some point in the a.c. cycle all flux disappears from the air gap and the iron particles can be jarred out just as if they were dirt.

To clean filings from a p.m. speaker, remove the cone and push electrical (or tire) tape down into the air gap with a piece of stiff wire. Metallic slivers will adhere to the tape and be withdrawn with it. Never disassemble a p.m. magnetic circuit to clean the air gap, as this will weaken the magnet.

Foreign material in the air gap is a serious matter. Dust buttons (see Fig.



Courtesy General Cements Co.

Applying speaker cement to the inner edge of the cone apex so as to fasten in a dust button or dust cover.

22A) will prevent anything from getting into the air gap, but their use is by no means universal, particularly in older speakers.

► Most foreign objects enter the air gap when the speaker is removed for servicing and laid face up on the work-bench. Dirt from the ceiling, particularly if you have a basement shop, may fall into the cone and work its way into the air gap. A piece of cloth over the speaker will prevent this, or you can place the speaker face down. Set it on

a piece of newspaper to prevent the field from drawing metallic slivers off the bench into the gap.

Whenever the cone is removed for any reason, cover the air gap with Scotch tape and remove the tape just before you install the new cone. This is particularly important with p.m. speakers, since their field strength is undiminished even with the set turned off.

## NOISES

A defective speaker may cause rattling and buzzing sounds. Each of these sounds will have its own characteristics, which can best be remembered after hearing them a few times. Let's see how some of these noises are produced.

If the cone is exposed to considerable heat in an enclosed cabinet, or if the field runs "hot," the cement holding the cone to the rim, the dust button to the cone, the cone to the voice coil, or the corrugated spider to the pole face may lose its holding properties. This causes sounds like those obtained by humming on a comb and a piece of paper. Speaker cement carefully applied will correct this trouble. Wait at least one half hour for the cement to dry before trying the speaker.

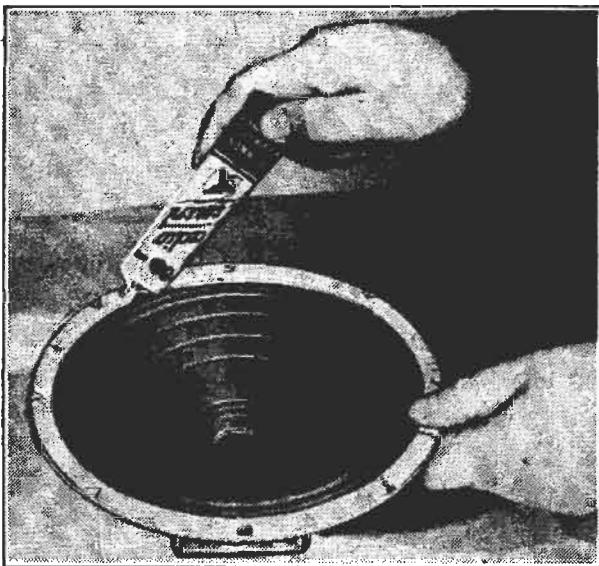
A spider leg may break under repeated movement; each time the broken pieces rub against each other the cone will produce noises. A replacement cone is the only solution.

Cone defects can also cause undesirable sounds. If the cone is torn, the torn sections may vibrate and produce sound waves by striking against each other. Scotch tape under and over the tear will often fix this. Holes poked in the cone can be repaired in the same way.

In some cases the cone material may dry out and become brittle; the cone

may then rattle when power is fed to the speaker. This calls for a new cone.

► The cones of speakers safely mounted in their cabinets do not become torn or have holes punched in them. A careless serviceman is usually responsible for such mishaps. Never put the speaker on top of the chassis when carrying the "works" to and from your car; if the speaker is face down it may slip and allow some sharp corner on the chassis to rip or tear through the cone. To carry a speaker properly in a car, place it face down on a seat, not on the floor. When you



*Courtesy General Motors Co.*

Applying speaker cement to a loose cone gasket ring.

reach for a speaker, don't just stick out your hand and grab—your extended fingers may go through the cone. If you must pick up a speaker with one hand, take hold of the pot—not the rim to which the cone is fastened, or the frame. If you treat speakers with care, you won't be likely to damage them.

► In a few cases you will find that signal-distorting rattles and buzzes are in sympathy with the cone vibration but are not caused by a speaker defect. Loose chassis and cabinet parts—

particularly celluloid dial shields on plastic cabinets—may be to blame. A little speaker cement will permanently anchor a dial shield in place. Speaker cement can also be used to fix loose push-buttons or anchor voice coil leads which whip against the cone.

Loose tube shields will sometimes buzz sympathetically. You can locate the offender by barely touching it with the back of a finger nail—you will feel the vibration and may change the tone of the buzz. To correct, bend the shield to a tighter fit.

► In phono-radio combinations, a very annoying buzz will frequently be set up when a signal is fed to the speaker. You will usually find one or more steel phonograph needles hanging onto the pole face near the cone, particularly with p.m. speakers. When the cone moves, it strikes the needles and a cone buzz results. Always pick off any needles adhering to a pot, even though they do not produce a buzz at the moment.

### EFFECTS OF AGING

Aging of the loudspeaker cone can also cause noise and distortion. A cone subjected to considerable heat will eventually dry out and become brittle, causing a loss of high-frequency response and perhaps a rattle. The only cure is to replace the cone.

When new, the cone is carefully balanced. It weighs just so much, and has a particular shape best suited to give a desired response. Dust collecting on the top surface of the cone will cause a weight unbalance, and distortion, in time. Too, the cone may absorb moisture and thus increase greatly in weight. This moisture may also soften the cone, resulting in a loss of both low and high frequencies.

The edge or rim of the cone undergoes considerable strain as the cone

vibrates back and forth. The ring between the actual cone and the speaker frame may break or become fatigued, particularly if it is leather. There may be very little physical evidence of aging. However, the tone quality of the receiver will not be all that might be expected from it. If a receiver is being peped up, replacing a cone that is several years old is a good idea.

## ELECTRICAL TROUBLES

The most common electrical trouble in a speaker is an open field coil. However, there may also be an open voice coil, a high-resistance joint in the voice coil circuit, or shorted turns in the speaker field.

Resistance in series with the voice coil will, of course, make the signal energy divide between the resistance and the voice coil. This cuts down output. This "high-resistance connection" may mean that a connection has changed from practically zero ohms to just a few ohms—4 or 5 ohms is a high-resistance value in a voice coil circuit, where the impedance of the voice coil itself may be only 2 to 6 ohms. Weak reception will be the only complaint, unless the loading effects of the voice coil on the output tube are affected enough to cause distortion in the output stage.

An open voice coil will usually cause a dead set. An ohmmeter will show either an open voice coil or high resistance, after disconnecting the coil so as not to get a false reading through the output transformer secondary.

► The usual speaker field difficulty is an open, which can be found with an ohmmeter. As another easy test, hold a screwdriver near the magnetic air gap in which the voice coil moves. With the set turned off, see how much pull is caused on the screwdriver by

the residual magnetism in the field assembly. Then turn the set on. If the field is energized, the screwdriver will be attracted much more strongly than by the residual magnetism. If there is no increase in the pull, the field is open or is not being energized.

Incidentally, this is one way of magnetizing a screwdriver if you want such a device to pick up small nuts or bolts in inaccessible corners of a radio chassis. Just hold the screwdriver near the air gap while the field is energized and it will be magnetized.

► It is not safe to wear a wrist watch when working on loudspeakers—the watch may become magnetized. While a jeweler can demagnetize it for you easily, sooner or later a balance spring will have to be replaced if the watch is repeatedly magnetized and demagnetized.

► The effect of an open field depends on how the speaker field is connected in the circuit. If it is used as a choke coil in either the positive or negative side of the filter circuit, an open field will interrupt the B supply for the receiver, so the receiver will naturally be dead.

On the other hand, if the speaker field has its own excitation supply, or is connected between B+ and B— as in many a.c.-d.c. receivers, an open field will cause very weak reception (also distortion). Reception also becomes weaker and distortion develops when the magnetic level of a p.m. speaker goes down.

A break in the speaker field is almost always caused by electrolysis or by excess current flow through the field. Electrolysis corrodes the field winding. Excess current causes overheating which will eventually open the winding—usually near the inside of the field, where the heat is greatest. A break caused by electrolysis is very

frequently right at the field terminals where the winding itself, made of rather small wire, is connected to heavier leads which emerge from the field enclosure. Sometimes you can cut the paper or tape wrapped around the field and expose these terminals. If the break is right at a terminal, you can often make a new connection, but the

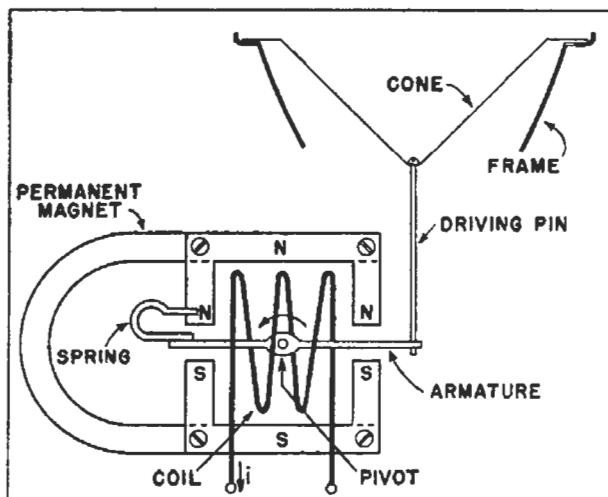


FIG. 24. The "works" of a magnetic speaker.

field must be replaced if the break is inside the winding.

► Weak reception and excessive field coil heat may indicate shorted turns. (Don't be surprised at the heat coming from the field coil even under normal conditions, however. Most loudspeaker fields dissipate about 8 watts of power, which will definitely make them uncomfortable to the touch after operating for a while.)

To check for possible shorted turns, allow the speaker to heat up for a half hour or longer, then measure the resistance of the winding while hot. Compare the measured value with the field resistance marked on the schematic diagram of the receiver. Usually such shorts develop between layers, so an appreciable change in resistance will be noticed.

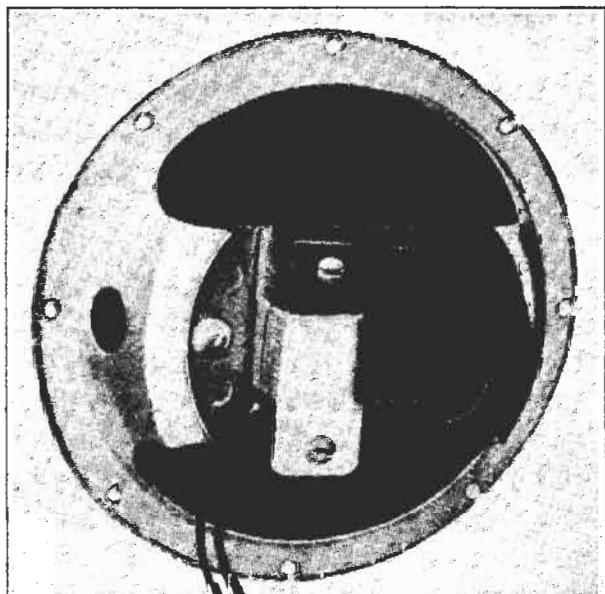
### MAGNETIC SPEAKERS

A picture and a diagram of a typical

magnetic speaker are shown in Fig. 24. These speakers are used in inexpensive a.c.-d.c. midgets, in some intercommunication systems, and as extension speakers.

When a signal is applied to the armature coil, the armature (which is pivoted in the center) swings back and forth in accordance with the shape of the signal wave form. The armature motion is transmitted through a driving pin to the cone. This pin usually passes through and is soldered to a metal cap fitted to the cone apex, as shown in Fig. 25. In some larger speakers, the solder may be replaced by a nut.

The power-handling ability of a magnetic speaker is slight; if excess signal is fed to it, the armature may



A picture of a magnetic speaker unit.

move enough to strike the pole pieces. Thus, noise can be created by overloading. Turning the volume down will clear this up.

► Trouble in magnetic speakers is generally caused by: Crushed cones; cones torn or fatigued around the metal apex cap; loose electrical connections; general cone fatigue, causing improper centering of the arma-

ture and allowing the armature to hit the pole pieces; iron filings in the air gap; loose driving rods; open armature coils; and loss of magnetism.

Damaged cones or loss of magnetism will usually cause weak, distorted reproduction; a new speaker is the best solution. Loss of magnetism can be identified by checking the output tube and the voltages applied to it. If everything seems to be normal, yet a circuit-disturbance test performed on the output tube gives only a weak thud or click, the speaker is at fault. If it has no electrical or mechanical defects, the only other possibility is loss of magnetism. The final test is, of course, to try another speaker.

Naturally, loose parts or connections should be tightened and filings in the air gap removed.

► Loud chattering sounds are caused by the armature hitting the pole pieces—recentering should be attempted. Some speakers have screws permitting armature adjustments, but most do not. If no adjustment is visible, see how the driving pin is attached to the cone. If a nut is used, screw it tighter; this may offset the sagging of a fatigued cone and recenter the armature between the pole pieces. If the pin is soldered to the cone cup, touch the tip of a soldering iron to the joint, taking care not to burn the cone. When the pin has loosened, the armature may move to its natural position. Remove the iron, let the joint set, and try the speaker.

If the armature has not recentered itself, slip shims (thin metal or paper

strips) between both sides of the armature and the pole pieces so the armature is blocked in the center of the gap. Then apply the soldering iron to the junction of the driver pin and the cone cup. When the solder melts, the cone will move to its normal resting position. Allow the joint to reset itself, remove the shims and test the centering—it should be correct.

If no shims are available, or cannot be introduced in the gap, notice the armature position and determine where the cone should be on the driving pin to center the armature. Apply the iron to the joint and move the cone manually to the proper position. Let

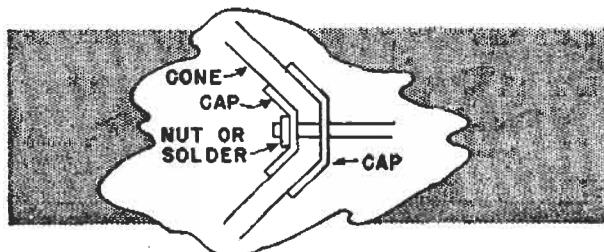


FIG. 25. How the magnetic driving unit is connected to the cone apex.

the joint set before testing the speaker. Repeat this procedure if necessary.

► Test the armature coil with an ohmmeter when an open or short is suspected. Watch for an erratic ohmmeter reading; this will indicate a partial open in the coil which will cause machine-gun-like bursts of noise when the system operates. Coils cannot be repaired unless the break is plainly visible. Since most jobbers do not stock replacement coils, the speaker should be sent off for an overhaul or a new speaker should be installed.

# Speaker Repair and Replacement

In dealing with speaker troubles, there are always four courses you can take. You can: 1, try to repair the defect; 2, install a replacement part; 3, send the speaker back to the manufacturer, take it to your local parts jobber, or send it to a firm specializing in speaker repairs;\* or 4, install a new speaker.

As a general rule, the cost of the cone plus your time is greater than the cost of a new speaker for midget a.c.-d.c. or three-way receivers. If you replace an open field coil, it is usually best to replace the cone at the same time, since cones deteriorate rather quickly. Thus, an open field in an inexpensive receiver requires a complete replacement speaker for best customer satisfaction.

With larger speakers this is not so true. Repairs or overhaul may be the best procedure. Of course, no repair should be attempted if the response of the speaker would be affected. And, as mentioned before, cones should be replaced rather than repaired if they are several years old.

Let us see how cones and fields can be repaired.

## REMOVING CONES

The first step is to examine the speaker carefully to see what kind of spider and rim mounting hold the cone in place.

In many older speakers, the cone rim is held by a metal ring bolted to the rim of the speaker frame. You can easily release the edge of the cone by unscrewing the bolts. The internal

\* If you cannot locate such a firm near you, your favorite radio supply house undoubtedly can get the speaker repaired for you.

spider shown in Fig. 22C was also commonly used in the earlier speakers. Detach the spider by unscrewing the screw holding it to the center pole piece, then disconnect the voice coil leads, and you can lift the cone and voice coil assembly out of the speaker frame.

► In most recent speakers, the edge of the cone is glued to the speaker frame. If the cone is to be removed and then replaced, paint the rim with a radio service solvent. This liquid softens the cement holding the cone and its spacing ring to the speaker frame so you can lift out the edge of the cone. If the cone is to be destroyed and a replacement used, you can run a knife around the edge, cutting the cone out entirely.

Again, you must disconnect the spider and the voice coil leads before the cone can be removed. If the spider is an external type secured by cap screws, remove them with an end wrench. Sometimes thin-nose pliers can be used, but the screws are in a rather awkward position between the cone and the frame supporting the cone. You thus have to work through holes in the frame which do not allow much room.

If the spider is a corrugated paper type, you can loosen it with a solvent or cut it off with a knife.

After removing the cone and voice coil from the speaker, carefully scrape off any paper adhering to the rim of the speaker frame or to the pole face. Clean the air gap thoroughly, using a small hand pump to blow out dirt and using a piece of tape to extract iron filings. Methods previously described can also be used.

► Do not destroy the heavy card-

board rings around the cone rim unless new rings are supplied with the replacement cone. These rings are used to position the cone so the voice coil will not be too far back in the air gap. Another ring is then used on top of the cone as a gasket. Sometimes this gasket ring is the only one used.

### INSTALLING CONES

Presuming you have the proper replacement cone, installing it is the reverse of removing the original cone.

If spacing rings are used, apply a coat of speaker cement on both sides of the bottom ring and both sides of the cone rim. Set the lower ring in place on the speaker frame rim and install the cone with the voice coil in the air gap. Be sure to position the

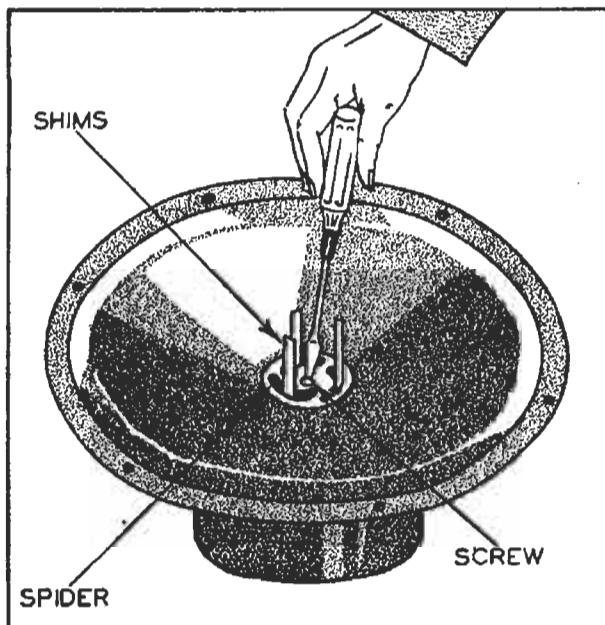


FIG. 26. How shims are used during adjustment of an internal spider.

cone so that the voice coil leads come near the speaker frame terminals. These leads must be looped away from the cone and directly back to the point of connection, not wrapped around the cone. If an external fiber spider is used, the spider legs must line up with the mounting supports.

Next, coat the outside ring or gasket

with cement and press it onto the cone, sandwiching the cone rim between the outer and inner rings. While the cement is still wet, adjust the position of the cone rim so as to center the voice coil approximately.

After the cement has set, center the voice coil with speaker shims or a cen-



Courtesy General Cement Co.

Withdrawing shims from a speaker having an external spider, after making the adjustments.

tering gauge. Speaker shims are thin strips or spacers (see Fig. 26) which are placed equal distances apart in the gap between the voice coil and the center pole piece, and thus hold the voice coil equally spaced from the center pole piece. Shims come in various thicknesses for different speakers.

A centering gauge is shown in Fig. 27A. These gauges are intended for specific speakers or voice coil spacings and cannot be used universally. Before the cone is installed, the gauge handle is passed through the voice coil and the gauge then pulled up within the coil. It spaces the voice coil from the center pole piece as shown in Fig. 27B.

With shims or a gauge holding the voice coil in the proper position, tighten the screws or bolts which anchor

the spider in place. If a corrugated paper spider is used, treat the edge of the spider with speaker cement and fasten it to the pole face of the speaker.

Allow the cement to set before removing the shims or gauge. Then solder the voice coil leads in place, positioning them so they will not whip against the cone.

To check the centering of the voice coil, remove the gauge or shims, then move the cone and voice coil assembly in and out by pressing against the cone rim with your fingers, applying equal pressure to both sides. You should hear no scraping sounds.

If you find the cone is properly installed, cement the dust button or dust cap in place, if one is used.

Next, connect the speaker leads to the receiver. Turn on the set but do not tune in a program. If the hum level is abnormally high, the voice coil may be connected backwards to the hum-bucking coil. Check by reversing the connections of the voice coil leads. If the hum is intensified, the original con-

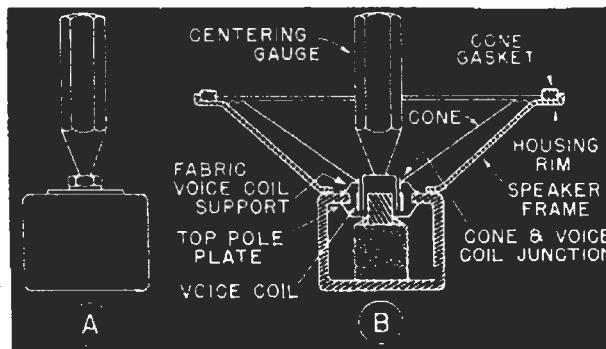


FIG. 27. Using a centering gauge.

nections were correct and the excess hum is caused by some chassis defect. However, if the hum is reduced, the last connection is the correct one.

Finally, try out the set to see if it sounds normal, with no scraping sounds or distortion.

► Sometimes the cone installation procedure will differ from the above

description, particularly where the cone is supplied separately from the voice coil. This type of construction is used chiefly with corrugated paper spiders, because it is difficult to glue down the spider with the speaker cone in the way. A typical replacement cone and voice coil assembly of this kind is shown in Fig. 28.

With this type replacement, cover the spider rim with cement and place the voice coil in the air gap, with the

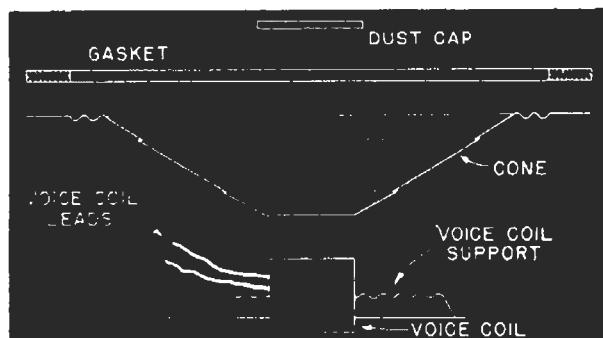


FIG. 28. A cone and voice-coil assembly which is put together during the installation of the replacement.

coil leads coming out toward the terminals on the frame. Use a centering gauge or speaker shims to center the voice coil properly. Next press the edge of the spider into place and let the assembly set long enough for the cement to harden.

At this point it is a good idea to solder the voice coil leads to the terminals on the speaker frame, as this is easier to do without the cone in place. Be sure to allow sufficient slack in the voice coil leads to permit free motion of the cone. Position the leads so they will be well away from the cone and speaker housing.

Apply a ring of cement around the rim of the speaker frame. (Some manufacturers also recommend coating the voice coil neck and cone apex with cement at this time.) Place the cone apex over the voice coil neck and press the cone rim tight to the speaker frame, using the voice coil as a guide. Allow

the cement to dry on the cone rim, then run a ring of cement around the junction of the cone and voice coil, being careful that the cement does not run inside the voice coil. After the cement has dried, remove the center gauge or shims. (The gauge should not be jerked out. Instead, turn it like a screw as you pull it out. Be careful not to apply such pressure that the voice coil is torn loose or the spider damaged.)

Cement the gasket in place around the cone rim. It's a good idea to turn the speaker upside down, so it presses

tion (Fig. 29) or a solid pot (Fig. 30). Notice that the yoke construction lets you see the field coil through the gaps at the sides of the yoke.

The speaker field fits around a center pole piece. This piece connects at the back either to the yoke or the pot, which forms a magnetic return path to the front pole plate of the speaker. Thus the magnetic field is concentrated in the voice coil air gap, between the front pole plate and the center pole piece.

To get the field coil out, you must

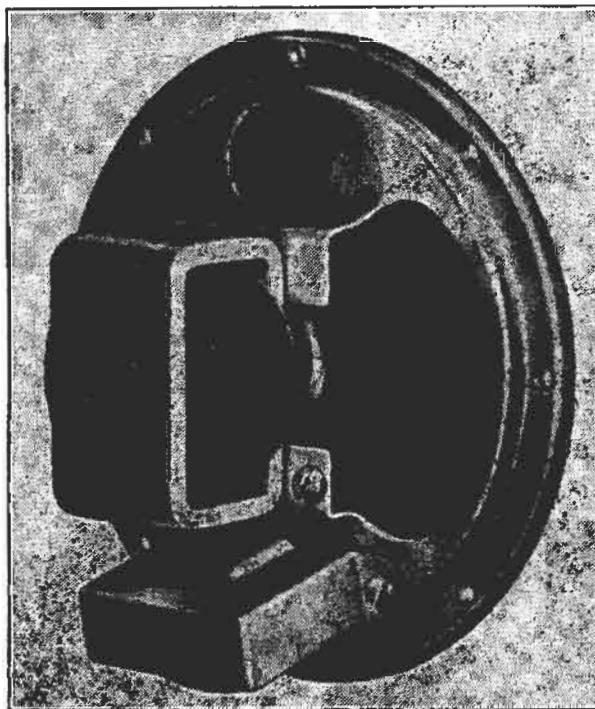


FIG. 29. This field enclosure is a yoke.

on the gasket while it is drying. Then cement the dust cap in place.

#### SPEAKER FIELD REPLACEMENTS

In some speakers a replacement field can be installed without disturbing the cone-voice coil assembly. In others, the moving system must be removed before the field can be replaced.

The first thing to do is to examine the speaker carefully. The pot in which the field is housed may be made in either of two forms—a yoke construc-

either remove the center pole piece and slide the field coil out of the yoke or, if the speaker has a solid pot, separate the front pole plate and pot so the field can be lifted out of the pot assembly. (If the pole pieces and pot are welded together, as they are in some speakers, you must send the speaker back to the manufacturer or get a new one.)

► If the speaker uses yoke construction, examine the rear of the yoke. If there is a large nut at the back of the speaker, directly behind the center pole

piece, just remove this nut. You can then extract the pole piece from the front of the speaker assembly, unless an internal spider is used. If one is, you must remove the cone and voice coil assembly before the field coil.

If the core is not held in place by a nut, it will be either pressed or swaged into the yoke assembly. Swaging, a process similar to riveting, can be identified by hammer and chisel marks on the rear of the core. As this fastens the pole piece to the yoke permanently, you must remove the entire yoke from the front pole plate. If the yoke is folded, as in Fig. 29, the assembly must be returned to the factory.

► The method of extracting a pressed core is shown in Fig. 31A. Hold the

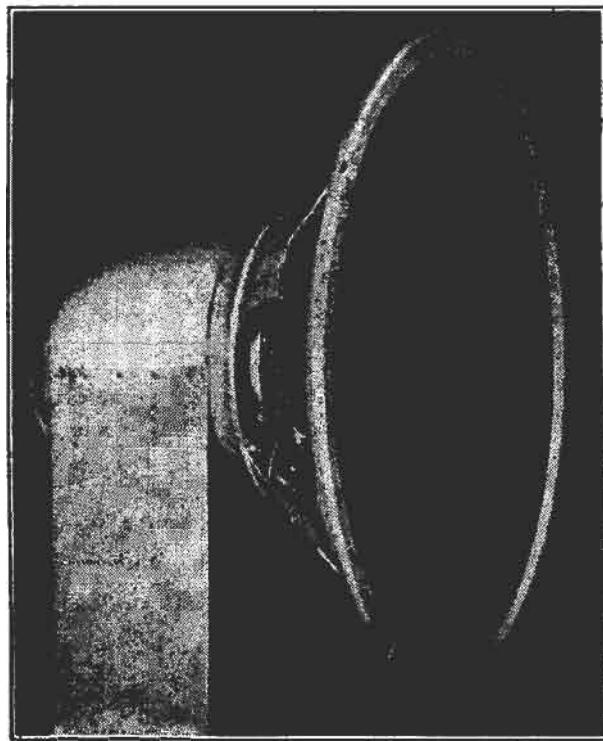


FIG. 30. The solid-pot type field enclosure.

speaker as shown, with the core over the opening between the jaws of a large vise (or over a board with a hole in it). Remove the dust button with a razor blade or sharp knife. Then, using a large piece of hardened drill rod or cold rolled steel, drive the core out the rear

of the speaker. Lift the field coil out of the opening in the yoke and install the replacement coil.

After replacing the field coil and putting all spacers and washers, the hum-bucking coil, and other parts in their original positions, reinsert the core through the voice coil opening and drive it into position as shown in Fig.

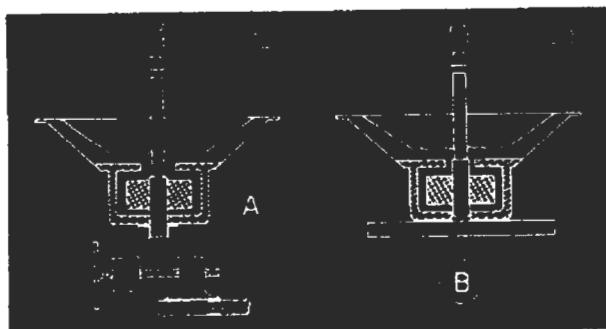


FIG. 31. How to drive out the core, and replace it, in the types having this feature.

31B. You must be very careful not to damage the voice coil. Drive the core straight down.

If the core is not centered in the voice coil opening, it may be centered by driving it from side to side, as necessary, with a center punch. A hole is provided in the front of the core for this purpose. Be sure to tap the center punch lightly, so as not to drive the core over too far and crush the voice coil form.

## TEST SPEAKERS

You can usually localize speaker defects by the methods given in this text. However, sometimes substitution of a test speaker speeds up the diagnosis. Regular test speakers mounted in cabinets for bench work are available and fill a real need in a large shop.

In general their construction is similar to that shown in Fig. 32. This outfit consists of an 8-inch p.m. speaker connected by a rotary tap switch to the secondary of a universal transformer. The transformer allows the voice coil

to be matched to any type or arrangement of output tubes.

To check a set which has push-pull output, connect terminals 1 and 3 to the plates of the power tubes and terminal 2 to B+. Disconnect the set output transformer, but leave its speaker field in the circuit. Turn the set on and adjust switch SW to give a match, indicated by least distortion. If results are satisfactory, you have definite proof that the receiver loudspeaker is defective.

For a single output tube, use terminals 1 and 3, following the same procedure.

If the field of the original speaker is open and you wish to check the receiver to see if anything other than the speaker is defective, substitute the 10-henry, 100-ma. choke and the voltage divider  $R$  for the field. To substitute for the low-resistance field of an a.c.-d.c. set, use terminals 6 and 7; for a tapped field, use terminals 7, 5 and 4; for a field with no tap, use terminals 7 and 4. Adjust the sliders on  $R$  so the correct resistance is added in the circuit.

Of course, the field substitution sec-

tion is not used if the set being tested has a p.m. speaker.

► Even if you have a test speaker in the shop, never leave the set speaker at the customer's home. The set speaker may be faulty, and you may be quite

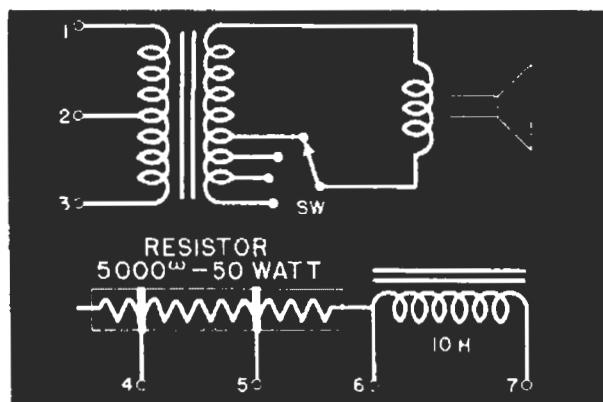


FIG. 32. A test speaker assembly.

embarrassed to find distortion, rattles or buzzes present after installing the repaired chassis.

Speaker troubles requiring the use of a test speaker are so rare that you are advised not to buy or build a test speaker until you have a large shop through which many receivers pass every day.

THE N. R. I. COURSE PREPARES YOU TO BECOME A  
**RADIOTRICIAN & TELETRICIAN**  
(REGISTERED U. S. PATENT OFFICE)

(REGISTERED U. S. PATENT OFFICE)

# Lesson Questions

Be sure to number your Answer Sheet 42RH-1.

Place your Student Number on every Answer Sheet.

*Send in your set of answers for this lesson immediately after you finish them, as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.*

1. In a properly operating class A stage, does the plate current change when signals are applied to the grid? *No*
2. Which TWO of the following operating voltage conditions will cause the tube to operate over the *lower bend* of its characteristic curve: 1, bias too low; 2, bias too high; 3, plate voltage low; 4, plate voltage high? *P5*
3. Why is an r.f. amplifier relatively free from amplitude distortion? *P5*
4. Suppose you have a resistance-coupled amplifier with a coupling condenser from the plate of one tube to the grid of the next. Explain briefly how leakage in this condenser causes distortion. *P7*
5. How can you determine whether a voltage found across a grid resistor is due to a gassy tube or to a leaky coupling condenser? *P8*
6. If tube  $VT_1$  in Fig. 13 burns out, will the symptom be: 1, hum; 2, distortion; 3, dead set; or 4, howling? *P8*
7. What defects would you suspect when distortion does not show up until the set has operated for at least a half hour? *Gassy tubes in  
heat warming the speaker can.*
8. Is voice coil rubbing more noticeable when low-frequency sounds or high-frequency sounds are being reproduced?
9. What is the best way of getting iron filings out of the air gap of p.m. speakers? *Push electrical tape into the air gap with a piece of stiff wire. When it is withdrawn the filing will come with it.*
10. If a speaker field is used as a choke coil in the filter circuit, what will be the symptom produced by an open field? *The set will be dead*